A Summary of Okanagan Chinook Information Requested by the Pacific Salmon Commission

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December 2019

Pacific Salmon Commission
Technical Report No. 42

The Pacific Salmon Commission is charged with the implementation of the Pacific Salmon Treaty, which was signed by Canada and the United States in 1985. The focus of the agreement are salmon stocks that originate in one country and are subject to interception by the other country. The objectives of the Treaty are to 1) conserve the five species of Pacific salmon to achieve optimum production, and 2) to divide the harvests so each country reaps the benefits of its investment in salmon management.

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For

Pacific Salmon Commission
Okanagan Work Group

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1 SUMMARY

The Okanagan[1] River is a Transboundary River with linkages to Chapters 1 and 3 of the Pacific Salmon Treaty (2019). The Okanagan River begins in British Columbia and flows southward for more than 300 km to enter the Columbia River near Brewster, Washington (Figure 1). Two runs of Chinook have historically returned to the Okanagan River: a spring run which returns in low numbers, and a summer run which is the focus of this report. Okanagan Summer Chinook are part of the Upper-Columbia Summer Chinook stock group that is represented in the PSC Chinook Model and has escapement and exploitation rate data reported by the PSC Chinook Technical Committee (CTC) annually. Upper-Columbia Summer Chinook return and spawn in five Columbia River tributaries (i.e. Wenatchee, Entiat, Chelan, Methow, and Okanagan) and return to the Wells and Chief Joseph hatcheries located on the mainstem of the Columbia River. Since 2002, catches of Okanagan Chinook ranged from 2,800 to 10,700, with similar average catches in AABM (3,800) and ISBM (3,700) fisheries based on Coded-Wire Tag (CWT) and escapement data (escapement range: 3,400-13,900).

During the development of the 2019 PST Agreement, concerns for the conservation and rebuilding of Okanagan Summer-run Chinook that spawned in Canada were discussed and there was interest in using the Okanagan Summer Chinook for an escapement indicator stock in Appendix I of the PST. Several questions arose during the discussions, and the Commission established a work group to explore issues including the establishment of management objectives, enhancement and possible use of the Okanagan Chinook as an indicator stock. The Okanagan Work Group (OWG) was assigned to develop concise summaries for each of the items in the Terms of Reference from the Commission (Appendix E).

Over the course of three meetings, one of which included a tour of both the Canadian and U.S. sections of the watershed, the OWG compiled the following responses to the Commission assignment.

1) Summarize existing information on the population structure of Chinook spawning in the Okanagan River.

Okanagan Chinook of today have resulted from a highly disturbed river system that has been recovering for about 70 years since the development of the Columbia River hydro-system, the Grand Coulee Fish Maintenance Program, extensive habitat impacts in the Canadian Okanagan River, and U.S. hatchery programs that inter-mixed several upper Columbia River summer Chinook populations. The population structure of Okanagan Chinook that existed prior to these activities is unknown.

Okanagan summer Chinook (in the US and Canada) are best regarded as a single population spawning across the border. The work group based this conclusion on the existing genetic evidence as well as the enhancement history of upper Columbia summer Chinook, the proximity of the large population in the U.S. to the small number of Canadian spawners, and the frequency of recovery of hatchery-marked U.S.

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[1] The name of the river, and the native peoples who lived in the watershed, is spelled differently on the two sides of the border. In Canada, the river is spelled Okanagan whereas in the U.S. it is spelled Okanogan. For consistency with the spelling used in the 2019 Pacific Salmon Treaty Agreement, this report uses the Okanagan spelling.

fish in the Canadian section of the watershed. Further, while genetic monitoring of spawning success in the Canadian Okanagan has been limited to-date, it has demonstrated successful reproduction and return of summer Chinook salmon to these habitats.

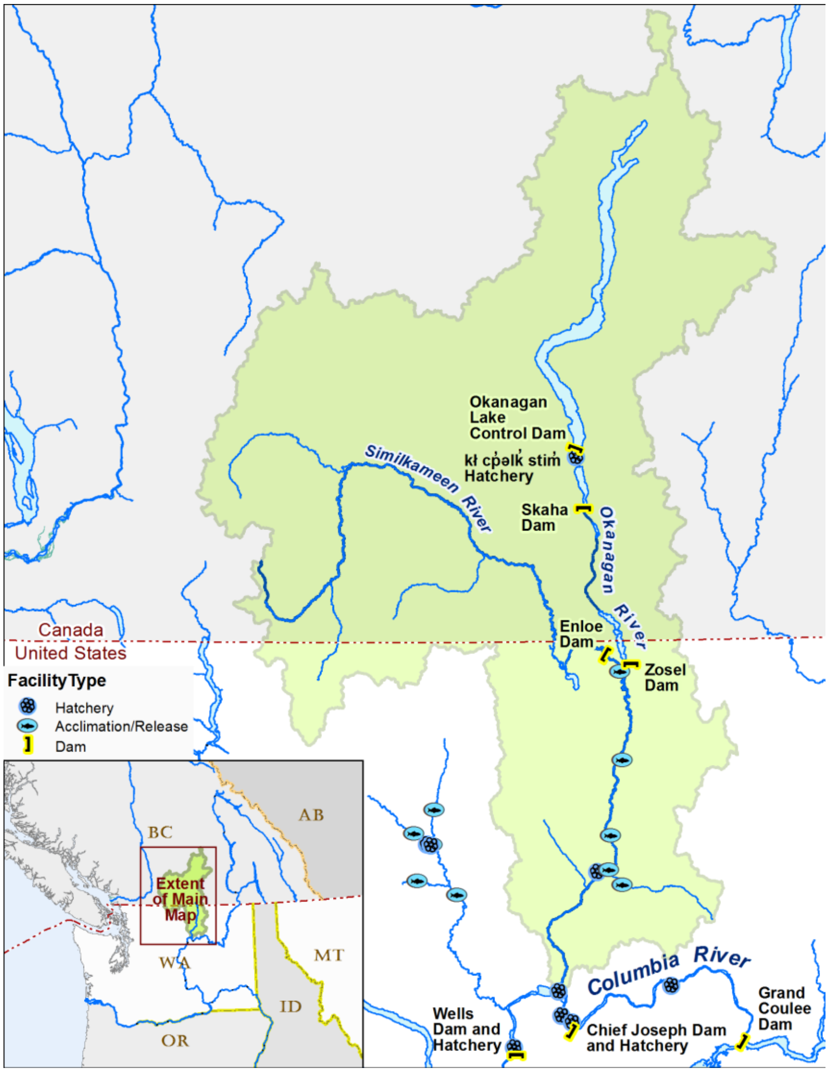

Figure 1. Map of the Okanagan and Columbia rivers.

2) <u>Summarize existing information on factors limiting the abundance, productivity, and spatial distribution of Chinook spawning in the U.S. and Canadian sections of the Okanagan River.</u>

Summer Chinook originating from the U.S. portion of the Okanagan appear to be remarkably productive. Their abundance over the last two decades has generally met or exceeded all spawning escapement objectives (Figure 2), even though they originate from a watershed with high stream temperature and sediment problems, migrate through nine dams and are subject to an array of fisheries from Alaska to the Okanagan watershed. The Chinook from the Canadian portion do not yet show a similar degree of productivity or production, though their spatial distribution in the watershed was limited by the

McIntyre Dam until 2009, and then by Skaha Lake Dam until 2014. The work group noted summer Chinook were less productive over a long period from the late 1960s to 2000, when abundances were chronically depressed. Factors that undoubtedly limited their abundance and productivity during that time included unregulated mortalities in the hydro-system, high levels of harvest in intercepting fisheries, habitat degradation in the Okanagan watershed (temperature, flow, sediment, unscreened diversions, predation, channelization), and a lack of supplementation programs. Almost all of those factors have been addressed to some degree, and when environmental conditions are favorable, the stock exhibits a high degree of productivity.

The OWG expects that the Canadian portion of the population will increase production once additional management actions, such as increased supplementation and habitat restoration, are implemented in Canada. Currently, temperature and oxygen conditions in the Okanagan River and Osoyoos Lake may affect adult distribution and survival before the spawning period and adult abundance has been quite low in the Canadian portion relative to the U.S. portion of the watershed (Figures 6 and 10). Historically, Chinook were self-sustaining in the Canadian Okanagan and supported First Nation fisheries.

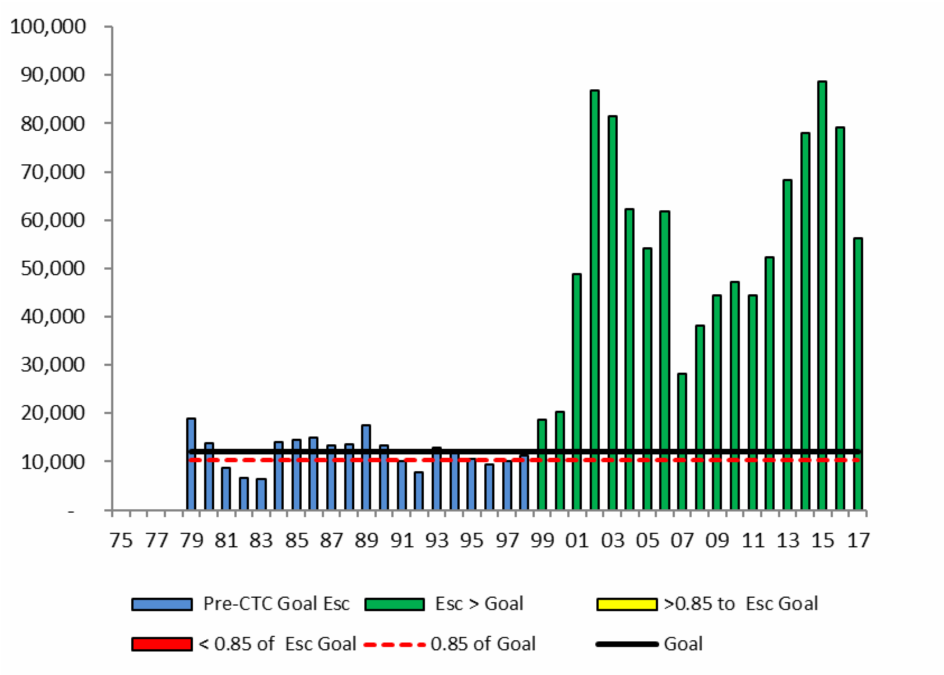

Figure 2. Adult Chinook salmon passing Rock Island Dam between June 18 and August 17; estimates include hatchery fish (generally less than 10% harvest occurs upstream of Rock Island Dam). This figure was taken from the PST CTC report 18-02 and the escapement goal is the management objective used by the CTC.

3) Describe existing actions to improve the abundance, productivity, and spatial distribution of Chinook spawning in the U.S. and Canadian sections of the Okanagan River.

The OWG documented many ongoing activities on both sides of the border that will result in improvements to abundance, productivity and spatial distribution. Freshwater habitat conditions have been improved on both sides of the border, through restoration of river channel and associated riparian areas, improving instream flow and water management, fish passage improvements, and removing mortality sources such as unscreened irrigation diversions. In the mainstem Columbia River, mortality resulting from passage through the hydro-system has been reduced due to modifications to the operating licenses for five Mid-Columbia dams that established performance requirements for each project, and by implementing operational changes and physical modifications to the four federal dams in the lower Columbia. Harvest regimes have been modified to account for variations in productivity and abundance of summer Chinook, through changes to the Chinook Annex of the PST, development of abundance-based management frameworks for US v Oregon fisheries and Colville and WDFW managed fisheries, and a Pacific Fishery Management Council (PFMC) framework that limits ocean harvest to meet weak stock objectives. Supplementation programs have been developed that meet established scientific principles for providing demographic benefits while minimizing genetic risks that hatchery origin fish can pose to natural populations.

4) Provide existing fishery management objectives for Chinook spawning in the Okanagan River.

The work group identified four different management objectives that directly affect Okanagan summer Chinook; each was developed for a different suite of fisheries, and none of them are directly comparable. The CTC uses an escapement objective for the Columbia summers stock group for fisheries regulated by the PST. The US v Oregon parties have established an objective for the upper Columbia summer Chinook stock group for fisheries in the mainstem Columbia downstream of McNary Dam. WDFW and the Colville Tribes have agreed on a biologically-based management objective for the U.S. Okanagan Chinook in particular, which is used to guide non-Indian fisheries upstream of McNary Dam and Colville fisheries. Canadian managers have identified a Recovery Target to guide restoration efforts in the Canadian portion of the watershed.

A biologically-based escapement objective has not been developed for the transboundary Okanagan watershed.

Canadian Recovery Target

There is now compelling evidence that the loss of genetic variation in small populations is strongly associated with its chance of extirpation. Consequently, in the field of conservation biology, guidelines for minimum viable population (MVP) size have been developed to reduce the rate of loss of genetic variation and sustain breeding populations. While there is an extensive scientific literature on MVP and different species, Wood and Bradford (2004) provide a useful summary of this topic for Pacific salmon and the development of recovery targets for several Canadian conservation units (similar to the U.S. evolutionary significant units).

The Recovery Potential Analysis (RPA, Mahony et. al. 2019) for Canadian Okanagan Chinook salmon recommends a recovery target of 1,000 spawners (based on a 4-year geometric mean) and the need for a positive trend toward in population growth. While this target is a general conservation guideline not associated with the actual spawners observed in the Canadian Okanagan River, the RPA also notes that "there is no indication that the current availability of spawning habitat would limit the recovery of Okanagan Chinook Salmon at any stage, given the current abundance of observed salmon." However, the RPA also notes that it is very unlikely that recovery target would be achieved in 12 years under current conditions (3 generations), unless supplementation of natural spawners was also undertaken ("supplementing the population with hatchery Chinook from the upper Columbia River"). For comparison, estimates of spawning habitat capacity in the Canadian Okanagan range from 2,920-8,680 spawners based on measurements of stream flow, depth and substrate, and an abundance of 3,400 spawners is estimated to produce the maximum sustained yield (Davis et al. 2008).

In the context of the assignment to this working group, Canadian members must respect the advice to government included in the Scientific Advisory Report (Mahony et. al. 2019), but the recovery target does not preclude the development of interim recovery targets developed as part of an integrated recovery program involving the local natural spawners plus a collaborative supplementation program. Further, as a component of a much larger meta-population in the Okanagan River, we note that the much larger abundance in the US side provides a buffer for genetic and demographic risks to the Canadian Okanagan. To restore and maintain a Canadian Okanagan Chinook population, it will be necessary to monitor the contribution of supplemented fish, productivity of Chinook in the Canadian habitats and downstream, and the possible divergence of characteristics over time.

5) <u>Compile existing information on opportunities to enhance the productivity and abundance of Chinook salmon spawning in the U.S. and Canadian sections of the Okanagan River (habitat restoration; supplementation; water management).</u>

Opportunities exist to restore the Okanagan summer Chinook spawning population in the Canadian portion of the watershed.

a. Several habitat restoration programs are underway, such as restoring spawning gravel bars, the removal of vertical drop structures (Figure 3), setting back levees and reconnecting channels, restoring riparian conditions, and additional opportunities have been identified.

b. The OWG discussed the potential for initiating a bilateral supplementation-based restoration program, relying on broodstock facilities in the U.S. and rearing/acclimating facilities in Canada, to facilitate testing uncertainties and restoration of a summer Chinook population in the Canadian portion of the watershed. While the OWG found that existing facilities will require some modifications to support a restoration program, it did not uncover any major impediments to a program.

Preventing the spread of Northern Pike into the Okanagan watershed will be critical to maintaining the productivity of Chinook in the watershed. Predation by other non-native fish will pose problems for restoration of Chinook in the Canadian portion of the watershed; a restoration program will need to address existing predation issues as well as preventing the arrival of Northern Pike.

Figure 3. Vertical drop structure #17 downstream of Okanagan Falls, B.C.

6) <u>Describe the current summer Chinook CWT indicator stock and identify whether any limitations exist in using it to monitor fishery impacts on Chinook salmon spawning in the Okanagan River.</u>

The CTC uses summer Chinook released on site at Wells Hatchery as the CWT indicator for the Mid-Columbia summer Chinook stock group. Wells Hatchery CWT fish were released from 1976-1978 (providing 1979-1982 base period recoveries), and have averaged about 750,000 CWT released fish annually since 1995.

This indicator stock is a mix of subyearling and yearling releases. Naturally spawning summer Chinook display an ocean-type life history strategy, however, the releases from hatcheries in the Mid-Columbia are predominantly from yearling reared fish. For this reason, the US v Oregon TAC forecasts and reconstructs the combined run of natural origin, hatchery subyearling and hatchery yearling summer Chinook. The combined forecast and reconstruction results are important inputs to the PSC Chinook

Model, which is used to set pre-season catches in ocean AABM fisheries. For consistency between the CWT indicator stock and the PSC Chinook Model stock, subyearling and yearling releases from Wells Hatchery are pooled together to form a single indicator stock.

There are several limitations of using this indicator stock to estimate fishery impacts on Chinook salmon spawning in the Okanagan River. As described above, the indicator stock is a mix of subyearling and yearling releases, but the natural spawning summer Chinook in the Okanagan display an ocean-type life history strategy. Additionally, broodstock collection for this indicator stock occurs at Wells Hatchery, downstream of the Okanagan River, so it does not provide escapement or terminal fishery impacts specific to the Okanagan River. Finally, the Wells stock is not double-index tagged, which precludes estimating the differential mortality impacts resulting from mark-selective fisheries. Thus, the Wells exploitation rates overestimate impacts to natural production (unmarked fish).

During the course of the OWG discussions, it was identified that considerable CWT data exist for the Okanagan River summer Chinook, however those data had not been analyzed using the cohort analysis program of the CTC until now. The OWG has conducted the cohort analysis and results are summarized in this technical report (Appendix B). The analysis identified differences in exploitation patterns among major PSC fisheries (Figure 4). There are also differences in the maturation patterns, with Okanagan yearlings having an older maturation pattern than Wells yearlings.

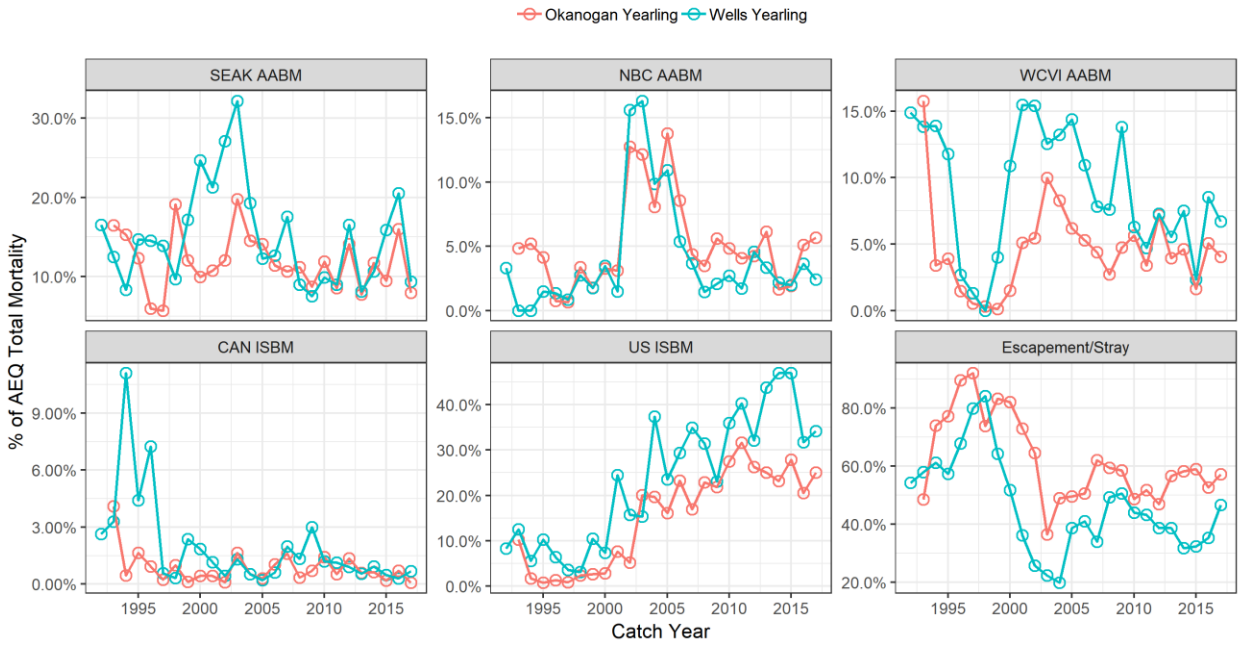

Figure 4. Catch year exploitation rates for yearling CWT Chinook originating from the Okanagan River2 and from the Wells Hatchery for major PSC fisheries and escapement.

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[2] The exploitation rate analysis for the Okanagan River summer yearling Chinook is a new analysis summarized in Appendix B.

7) <u>Discuss new information that could assist the Parties in more effectively implementing Chapter 1, Paragraph 7, which may include a discussion of options for additional management objectives or fishery obligations in U.S. and Canadian fisheries and whether adoption of those measures could benefit the abundance, productivity, and spatial structure of Chinook salmon spawning in the Okanagan River.</u>

In the U.S., Okanagan summer Chinook are part of the larger Mid-Columbia summer Chinook management unit in the PST and US v Oregon processes. The Mid-Columbia summer Chinook management unit is represented by a long time series of CWT releases from Wells Hatchery. Mid-Columbia summer Chinook escapement objectives are expressed as a single unit in the PSC and US v Oregon management processes. Terminal area returns are forecasted for the single management unit. The capability to manage for the individual components of Mid-Columbia summer Chinook in real time is not available within the PSC or US v Oregon processes.

Newly analyzed CWT data from the Okanagan Basin provide information on potential differences in spatial distribution, maturation rates and exploitation rates between aggregate Mid-Columbia management unit and the Okanagan summer Chinook. The new CWT information provides an opportunity to develop a specific Okanagan exploitation rate indicator stock. For instance, application of the CTC methods to analyze single-index tag (SIT) group for the effects of mark selective fisheries (MSF) would be useful for Wells and Okanagan index groups due to the degree of mark selective harvest in the terminal areas. The new exploitation rate data from the Okanagan would also be useful to re-evaluate the population dynamics for Okanagan Chinook and the spawning abundance that produces the maximum sustained yield. Development of other stock identification information, such as genetic stock identification, may also support determining the escapement objectives. Consistent escapement objectives across processes could help ensure management actions that accrue benefits throughout the range of the stock.

8) <u>Identify research projects that could promote the mutual, effective conservation of Chinook salmon spawning in the U.S. and Canadian sections of the Okanagan River.</u>

a. Confirmation of the meta-population structure of Canadian and U.S. Okanagan Chinook salmon. While analyses to–date support the conclusion of a single population across the border, these analyses involve limited sample sizes that should be enhanced. These data would also provide a baseline of genetic information for subsequent monitoring of supplementation and localized population structure. These studies should employ standardized methods.

b. Integrate annual monitoring projects for juvenile and adult salmon to provide estimates of annual productivity and temporal variation in Okanagan Chinook salmon (overall and by sub-populations).

    i. Examine the accuracy of escapement estimation programs in the U.S. and Canada and make improvements where necessary, using PIT tagging mark-recapture, or another approach. Determine whether there are missing components of returning adults potentially by applying ecological-DNA methods.

    ii. Examine pre-spawn survival and behavior of returning adult Chinook, specifically to evaluate the effect of the thermal barrier in Osoyoos Lake and the stray rate into the Similkameen River, a cool water refugium.

    iii. Juvenile monitoring of supplemental production should use coded-wire tags for cohort analyses and Passive Integrated Transponder tags (PIT tags) for detailed understanding of survival by life history stage and habitats within the Columbia watershed. PIT monitoring should include increased detection efficiency at Zosel dam (outlet of Osoyoos Lake) and increased monitoring sites within the Similkameen River.

    iv. Incorporate environmental monitoring to evaluate long-term impacts of climate on Okanagan Chinook salmon.

c. Design and maintain a CWT indicator population for the Okanagan/Similkameen summer Chinook salmon incorporating multiple release sites in Canada and the U.S. The marking program for this population should incorporate a double index tag group if adult production will be harvested in mark-selective fisheries, or apply the CTC SIT methods for MSFs.

d. Establish on-going monitoring for invasive non-native fishes and studies of predation by non-native fishes including for invasive Northern Pike (*Esox lucius*).

9) Recommend annual reporting needs to inform the Commission over time. See Advice to Commission below (Section 3).

2 ADVICE TO COMMISSION

This advice is based on our determination that the summer Chinook spawners on both sides of the border comprise a single population, is consistent with our response to questions #8, and builds on the existing programs by governments in the Okanagan River watershed. Investments to-date form the basis for an active restoration program enabled through supplementation efforts, habitat restoration and measures to improve juvenile and adult passage survival. Past efforts have included the development of a water management strategy, habitat restoration (past and planned), supplementation efforts in the US Okanagan, and establishing standards for and monitoring of downstream survival rates, and CWT information to manage downstream fisheries in the U.S. and Canada. The recent completion of the Chief Joseph Hatchery, located on the Columbia River near the mouth of the Okanagan, provides an egg-take source that is specific to the Okanagan watershed.

To benefit from past investments and on-going commitments, the work group advises:

1) Establish a bilateral advisory and science committee to aid in the development of supplementation, monitoring, and future research programs. This committee would provide an annual report to the Pacific Salmon Commission (Chinook Interface Group).
    a. Given the complex structure of Mid-Columbia River summer Chinook in the US and the recent recalibration of the CTC Chinook model, in the immediate term, the proposed restoration and monitoring of the Okanagan Chinook can be tracked separately and reported to the Commission.
    b. Future consideration of the Canadian Okanagan summer Chinook within the PST will require development and agreement on biologically-based management objectives.

    c. Separation of the Mid-Columbia River summer Chinook stock group into separate population units would require significant consultations and analysis, and is unlikely to be implemented within the term of the present Agreement.

2) Establish an annual supplementation program based on the current, successful efforts and utilizing hatchery facilities in both countries. This program would provide adult returns to habitats restored in the Canadian Okanagan and would provide fish to study survival of these out-planted juveniles through the Canadian lakes and altered stream sections (both countries presently utilize PIT tags for similar studies).
3) Establish a bi-lateral monitoring program to support and evaluate restoration efforts and incorporate survival rate studies of tagged summer Chinook and predator studies. Key objectives of the monitoring program would be to identify the limiting factors to production of summer Chinook in the Okanagan and Similkameen rivers, and development of a joint genetic monitoring program to further understand the population structure of Okanagan summer Chinook salmon, and the possible divergence of naturally-spawning Chinook in the Canadian Okanagan River.
4) Develop and implement a plan to prevent the spread of Northern Pike into the Okanagan watershed, and address existing predation issues as identified by the above studies.

3 PREFACE

The Okanagan River watershed extends from Deep Creek, near Enderby British Columbia, southward more than 300 km to the confluence with the Columbia River, near Brewster, Washington and drains an area exceeding 21,000 km^2 in Canada and the United States. The name of the river, and the native peoples who lived in the watershed, is spelled differently on the two sides of the border. In Canada, the river is spelled Okanagan whereas in the U.S. it is spelled Okanogan. For consistency with the spelling used in the 2019 Pacific Salmon Treaty Agreement, this report uses the Okanagan spelling.

There are both spring and summer Chinook returning to the Okanagan River (COSEWIC 2017; Armstrong 2015), however this report focuses on summer Chinook because that was the assignment from the Commission. Spring Chinook are referenced in a few sections in this report depending on context.

Okanagan Summer Chinook are part of the Mid-Columbia[3] Summer Chinook stock group that is represented in the PSC Chinook Model and has escapement and exploitation rate data reported by the PSC Chinook Technical Committee (CTC) annually. The CTC has used the escapement based on the adult Chinook counts at Rock Island Dam from June 18 to August 17 as the escapement indicator for the Mid-

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[3] The summer Chinook originating from the Okanogan, Methow, Wenatchee, Entiat and Chelan are variously referred to as either Mid-Columbia or Upper Columbia by different entities. For example, the CTC refers to them as Mid-Columbia while the NMFS classifies them as a part of an Upper Columbia Evolutionarily Significant Unit. In comparison, the U.S. v. Oregon parties define upper Columbia summer Chinook as the populations that spawn in the Okanagan, Methow, Entiat, Chelan and Wenatchee rivers as well as the mainstem Columbia River upstream of Rock Island Dam, and that generally pass over Bonneville Dam between June 15 and July 31 (2018-2027 United States v. Oregon Management Agreement). For precision, this report uses each entities' designation, without attempting to reconcile them.

Columbia Summer stock group (Figure 2). Within this stock group, Summer Chinook return and spawn in five tributaries to the Columbia River (i.e. Wenatchee, Entiat, Chelan, Methow, and Okanagan) and return to the Wells and Chief Joseph hatcheries located on the mainstem of the Columbia River.

4 HISTORICAL BACKGROUND

Available historical information indicates that Chinook salmon entered the Columbia River from early spring through early fall, with peak abundance in July. Most of the summer Chinook spawned in waters above Grand Coulee Dam, these were the fabled 'June hogs' whose large body size was an adaptation to both the length of the migration and their timing, swimming upstream during the main snowmelt. As the most abundant, the late spring and summer components of the Columbia River Chinook populations also contributed the most heavily to fisheries (McDonald 1894; Thompson 1951; Chapman 1986). Historic estimates of Chinook salmon mean catches for different periods (years) were approximately 400,000 spring Chinook (~1900), 1,700,000 summer Chinook (1881-1885), and 1,100,000 fall Chinook (1915-1919; Chapman 1986; NPPC 1987).

Although there is considerable uncertainty in the abundance of salmon before European immigration to the Pacific Northwest, records from the canning industry indicate that tens of millions of pounds of Chinook Salmon were harvested from the lower Columbia River (McDonald 1894). Additionally, tribal knowledge handed down through generations and statements from early settlers show that large quantities of big-bodied Chinook were harvested by tribes at both Celilo Falls (Netboy 1980; Hunn 1990) and Kettle Falls (Scholz 1985), and locally in the Okanagan basin at Okanagan Falls (Vedan 2002).

Summer/fall Chinook counts at Rock Island Dam from 1933 through 1942 averaged only 5,658 adults and jacks; these low numbers reflect the immediate detrimental impact of Grand Coulee Dam, which completely blocked most of the run from its spawning grounds. Based on dam counts and catch information in WDF/ODFW (1992), harvest rates on summer Chinook salmon below McNary Dam (Zones 1 – 6) could have ranged as high as 90% during that time period. Annual summer/fall Chinook counts at Rock Island remained less than 9,000 fish until 1951, when harvest rates in Zones 1 – 6 were reduced. Thereafter, Chinook escapements rose sharply, ranging most often between 20,000 and 35,000 Chinook, although a decade covering the late 1950s through 1960s had counts exceeding 60,000. However, Columbia River catches of summer Chinook increased during the late 1950s, but declined in the early 1960s (Chapman 1986), indicating a decline in the abundance of summer Chinook.

State fishery managers closed the commercial fisheries on summer Chinook in 1965 and minimized recreational fishery impacts shortly thereafter, as catch trends showed continuing long-term declines. Even though in-river fishery impacts were minimal, ocean fisheries in Alaskan and Canadian waters continued to intercept Columbia River summers, without regard to abundance until the Pacific Salmon Treaty was implemented in 1985. Spawning escapements remained low, but stable, until 1999 when a combination of factors apparently enabled summer Chinook to recover. These factors included improved protection measures for juveniles and adults passing through the hydroelectric system, more effective hatchery supplementation programs, increased productivity in the ocean environment and limits on the interception of summer Chinook in the ocean fisheries. Adult escapement increased in

2001 and has remained relatively high since, and a similar, although less pronounced, response occurred for the Okanagan population (Figure 5).

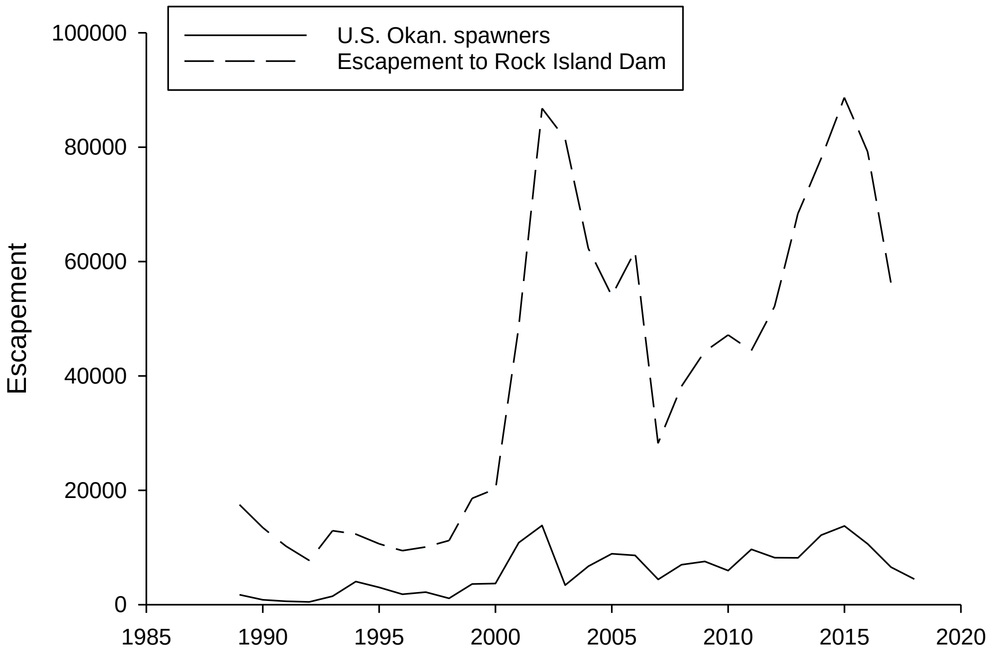

Figure 5. Escapement of summer Chinook to Rock Island Dam and to the spawning grounds in the U.S. portion of the Okanagan River.

Prior to a 2008 *United States v. Oregon* Agreement, the harvest management strategy implemented to protect the U.S. Endangered Species Act(ESA) listed Snake River spring/summer run through the lower river also greatly restricted harvest rates on summer Chinook returning to the Columbia upstream of Rock Island Dam. As a result, summer Chinook runs were lightly exploited in the Columbia River from 1965 when commercial fisheries were ended until 2008, when the ESA restrictions no longer constrained fisheries in the Columbia below the Snake River confluence. Escapements after 2008 continued to increase, an indication that the change in harvest management in the Columbia was consistent with the productive capacity of the population.

5 POPULATION STRUCTURE AND SPATIAL DISTRIBUTION

The summer Chinook of the Columbia are an "ocean type" Chinook (NMFS et al, 1998), and are closely related to other summer and fall runs in the Columbia Basin (Waknitz et al 1995). As a consequence, the 1995 review of Chinook populations in the mainland U.S. determined that the summer Chinook was a component of a large, healthy metapopulation of ocean-type Chinook, the Upper-Columbia River Summer and Fall Run Evolutionarily Significant Unit (ESU; Myers et al, 1998).

5.1 GENETIC POPULATION STRUCTURE

Chinook returning to the Okanagan River in Canada and the U.S. are part of the large meta-population of Columbia Summer Chinook, which is part of an ESU that also includes fall Chinook from the Hanford Reach of the Columbia River (Myers et al, 1998). These fish are genetically different from the Chinook populations that make up the spring-run, stream-type upper Columbia River ESU that spawn in some of the same watersheds (Beacham et al. 2006). The summer and fall Chinook are indistinguishable genetically, which suggests the populations have been homogenized or that there has been substantial gene flow among populations (Kassler et al. 2011). Summer Chinook currently return to the Wenatchee, Entiat, Chelan, Methow and Okanagan Rivers for spawning and some are collected by hatcheries located on the mainstem of the Columbia River below Wells Dam and Chief Joseph Dam. An unknown number also spawn in the Columbia River below Chief Joseph and Wells dams.

The genetic distinctiveness of the original populations has been extensively affected by dam construction and past hatchery practices, beginning with the Grand Coulee Fish Maintenance Program (GCFMP; 1939-1947), and variations that continued into the early 2000s (Johnson et al. 2018). Following construction of the Grand Coulee Dam, the GCFMP trapped and collected all summer Chinook at the Rock Island Dam that were migrating to the upper Columbia River. These Chinook were relocated to the Wenatchee, Entiat and Methow Rivers for spawning, since the early view in the Columbia River basin was that groups within a salmon species were interchangeable (Johnson et al. 2019). The OWG attempted to determine whether there were any systematic hatchery production or out-planting programs of Chinook into the Okanagan watershed following the initiation of activities to mitigate for expected anadromous fish losses with the blockage of the river from the construction of Grand Coulee Dam (Brennan 1938). The Working Group was unable to find any record of releases of Chinook into the Okanagan, but was also unable to determine with certainty that there were not any. The GCFMP is reported to have had a goal of removal of all anadromous fish passing upstream at Rock Island Dam from 1939 through at least to 1943 (Board of Consultants 1939). If the GCFMP actually achieved that goal, the impact on Okanagan summer Chinook was likely dramatic, eliminating four consecutive brood years. Based on the evidence available to the OWG, no conclusions can be drawn regarding either the potential elimination of those broods or whether natural spawning and production re-established following the cessation of the GCFMP activities at Rock Island Dam.

As a result of the GCFMP activities, all Chinook salmon now migrating past Rock Island Dam descend from a mixture of different Upper Columbia stocks, as evidenced by genetic homogenization (Kassler et al. 2011). This practice undoubtedly affected the genetic characteristics of the population structure that existed in the Okanagan, Methow, Entiat and Wenatchee rivers prior to the GCFMP. Subsequently, the Wells Hatchery collected summer Chinook that returned to the dam and progeny were released into the Methow and Okanagan rivers: these fish were called the MEOK stock because their parents were likely returning to the Methow and Okanagan Rivers. More recently, considerable developments have occurred with hatchery management and the Okanagan River enhancement has a brood stock collection approach that relies on fish returning to the Okanagan River. These new approaches use a high proportion of natural-origin fish to maintain the genetic integrity of the population (HSRG 2009; Johnson et al. 2019).

Of particular interest to the PSC is the population structure within the Okanagan River in Canada and the U.S. The Canadian Okanagan Chinook population is genetically distinct within Canada as there are no other Columbia River Chinook populations in Canada due to the extirpations caused by Grand Coulee Dam. But the Canadian Okanagan Chinook population is genetically similar to other populations in the U.S. Upper Columbia Summer/Fall ESU, which is genetically distinct from other U.S. ESUs or equivalents within the Fraser River (Myers et al. 1998, Waples et al. 2004). There is no information available to determine if the historic population in Canada was genetically or demographically distinct from the U.S. population.

Studies have examined genetic relationships among the Canadian Okanagan Chinook population and nearby U.S. populations including spawning populations in the U.S. portion of the Okanagan Watershed (Similkameen and Okanagan Rivers; Davis et al. 2008;Ruth Withler, pers. comm. 2019; Mahoney 2019). Adipose fin- clipped and CWT-marked adults present on the spawning grounds are direct evidence that U.S.-origin Okanagan Chinook have dispersed into the Canadian section of the Okanagan River (Davis et al. 2008). Dispersal is common among salmon populations that are nearby. Allelic frequency (the measure of how common a gene is in a gene pool) data show that there is a high level of diversity present in the Canadian Okanagan Chinook, but given how small the numbers of spawners are, this result likely indicates genetic input from a larger source population (Ruth Withler, pers. comm. 2019). These data suggest that the Okanagan Chinook in Canada are unlikely to be a self-sustaining remnant population that is independent from much larger populations in the U.S. section of the Okanagan. However, large numbers of adults returning from a few families returning in 2005-2006 indicates that successful spawning (in terms of producing returning adults) has occurred recently in the Canadian portion of the Okanagan River. Our interpretation of the limited samples from the Canadian Okanagan Chinook salmon is that the fish present in Canada are part of a much larger meta-population composed of U.S. and Canadian spawners and that the spawners observed in Canada are of both Canadian and U.S. origins.

5.2 SPATIAL DISTRIBUTION

In recent years the spawning escapement has occurred almost entirely in the U.S. portion of the watershed, with less than one percent spawning in Canada. In the U.S., Okanagan summer Chinook spawners utilize large mainstem habitats in the Okanagan and Similkameen Rivers from just upstream of the end of Wells Dam inundation (~25 River Kilometers (RKM) upstream of the confluence with the Columbia River) to Zosel Dam (RKM 125) at the outlet of Osoyoos Lake a few miles south of the border with Canada. The majority (> 70%) of summer Chinook spawning in the U.S. occurs in the upstream most reach of the Okanagan from Zosel Dam to the confluence with the Similkameen River and in the lower reach of the Similkameen River (Pearl et al. 2017). Since 2014, the Colville Tribes have been releasing summer Chinook in the middle reaches of the Okanagan River at the Omak Acclimation Pond to attempt to improve spatial structure and utilize under seeded habitat in the middle and lower portion of the watershed.

In Canada, historical DFO records show documentation of Chinook spawners (observed not enumerated) in the Okanagan River prior to the 1940s prior to the GCFMP, then observations periodically in the 1960s, and more recently in the 1990s (COSEWIC 2006; 2017). Since the 2000-2008 ONA has enumerated Chinook to be less than 50 returning adults (Davis et. al. 2008) and escapement was low from 2006 to 2018 (Figure 6). The Okanagan Nation Alliance (ONA) have been routinely monitoring the Okanagan River at the three designated sites described in the habitat section below (Figure 8). Primarily, most adult Okanagan Chinook Salmon have been reported spawning in the ‘index’ section of the river, noted as being in the most natural state relative to either the channelized or vertical drop section, both of which are highly channelized, or to the region upstream of the McIntyre Dam (Skaha section; only accessible after 2009). Surveys have resulted in carcass sampling rates ranging from 80%-100% (average 96%), and measured an average proportion of hatchery-origin fish of 10% over from 2006-2018 (Figure 7). The vertical drop section has had a decreasing number of spawners since 2006, however the index section had a stable abundance of ~40 spawners from 2013 to 2017. Moreover, one or two spawners have been observed in Shingle creek since 2011, which is within the region above the McIntyre Dam (accessible since 2009), suggesting the fish may continue to return to that area. Fish passage at Skaha Lake Dam was established in 2014 and since then, accessible range was extended to the outlet dam on Okanagan Lake in Penticton. While Chinook spawners are observed between Vaseux and Skaha lakes and in the Penticton Channel below Okanagan Lake Dam since fish passage was created, abundances are generally low compared to the natural ‘index’ section. Fish passage at Okanagan Lake Dam was established in 2019.

In addition to the above, there is new evidence that Spring Chinook Salmon are present in the Okanagan watershed. This is based on the detection of Passive Inductive Transponder (PIT) tagged fish that originated from the breeding of spring Chinook in hatcheries. Spring (stream-type) and summer (ocean-type) Chinook spatial distributions in the Okanagan basin are similar to the Thompson basin distributions in the Fraser River (spring Chinook in tributaries and summer Chinook in the mainstem rivers). Spring Chinook are smaller bodied Chinook that spawn in tributaries of the Okanagan basin while summer Chinook spawn in the mainstem Okanagan River. Spring Chinook have been detected in the Okanagan River PIT array near Oliver, B.C. since 2015, increasing from 3 to 30 between 10 June and 15 September 2018; (OBMEP 2019). Spring Chinook were subsequently detected in tributaries in the Okanagan basin such as Inkaneep, Vaseux, Shuttleworth, and Shingle creeks which are all downstream of the outlet of Okanagan Lake. Upstream of Okanagan Lake, there are 23 tributaries that will be accessible to spring Chinook now that an operational fishway has been installed at Okanagan Lake Dam (September 2019). During the same period less than two PIT tagged summer Chinook were detected each year (15 September to 19 October). In Canada, the summer Chinook spatial distribution are largely distributed in the mainstem river habitat downstream of Okanagan Lake outlet to Osoyoos Lake.

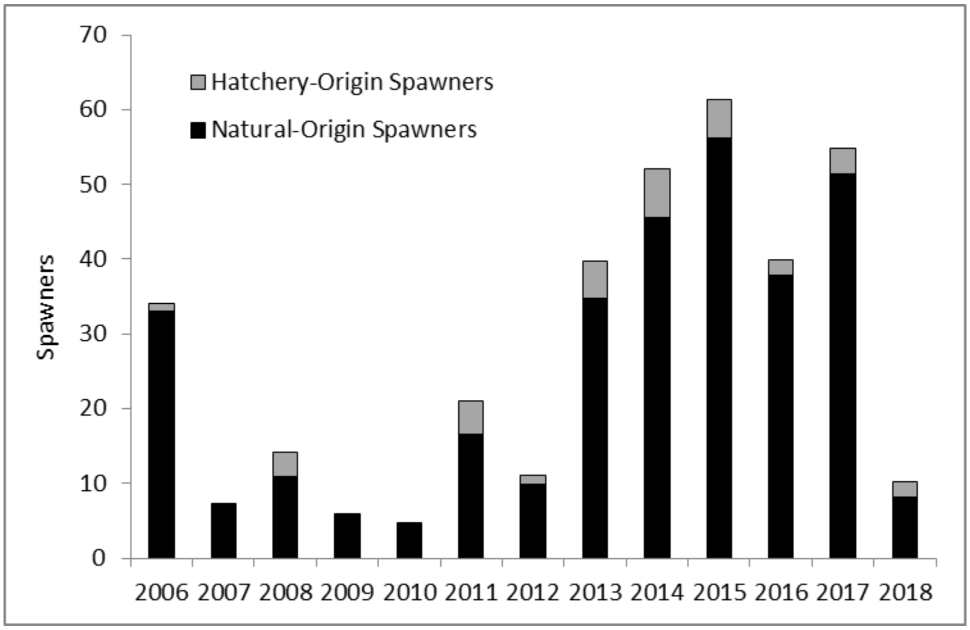

Figure 6. Area under the curve (AUC) escapement estimates for Okanagan Summer Chinook Salmon (2006-2018). AUC was calculated as per Neilson and Geen. (1981) and divided by a residency estimate of 7.7. Where the number of sampled carcasses exceeded the AUC estimate, the number of sampled carcasses is reported instead (2006, 2009, 2011-12). Counts are composed of fish enumerated in the Skaha, 'index' and channelized sections of Okanagan River. Data courtesy of ONA.

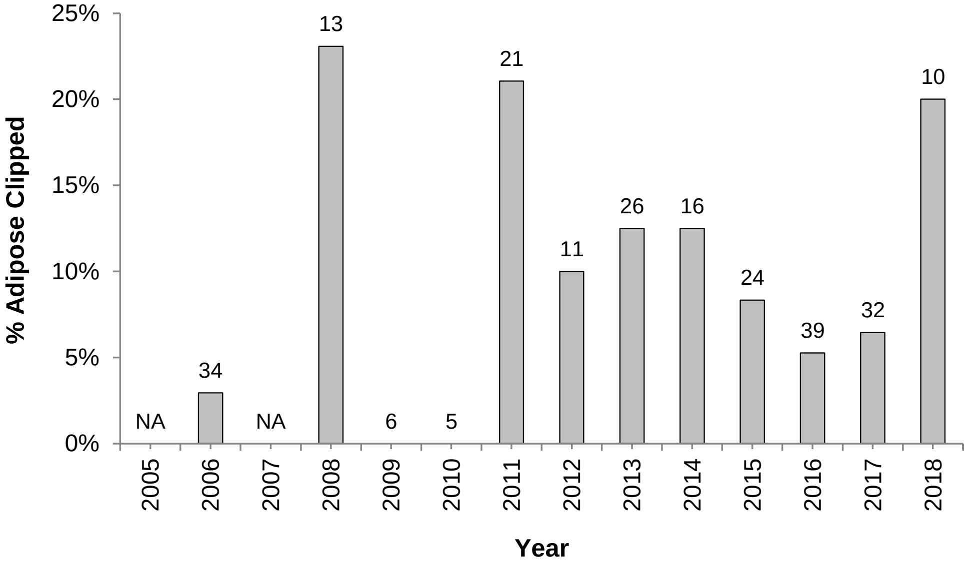

Figure 7. Percentage of adipose-clipped adult Chinook salmon collected from the Canadian portion of the Okanagan River from 2005-2018. Sample sizes are denoted above bars. Data deficient years are represented by NA. Data provided courtesy of ONA.

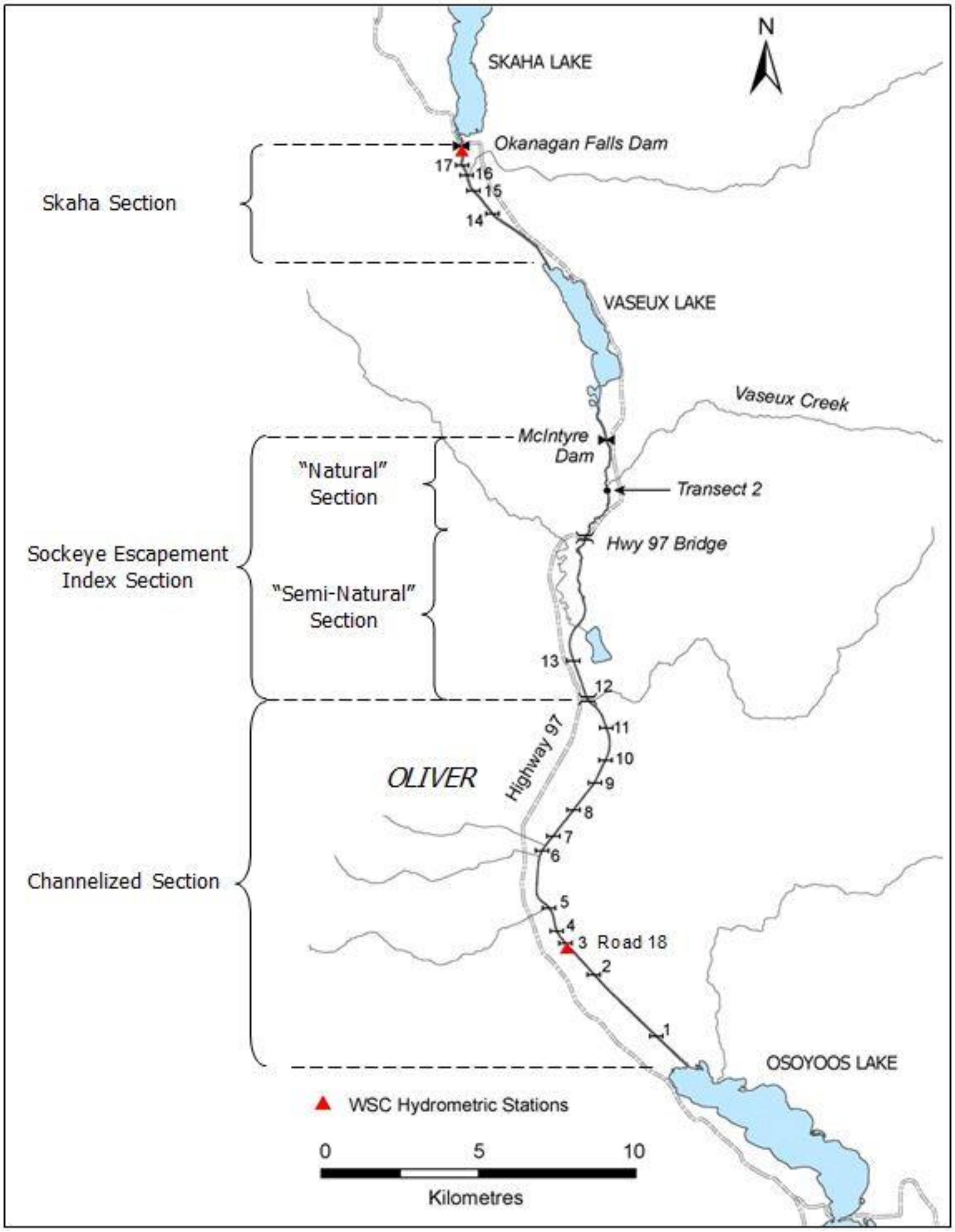

Figure 8. Location of spawning areas of interest for Okanagan Chinook Salmon in British Columbia. Numbered lines located on the river designate vertical drop structures that are built into the channelized sections of the river. Map courtesy of K. Hyatt. Not shown in this figure is a section of spawning habitat in the Okanagan River between Skaha and Okanagan lakes (Penticton Channel).

6 SPAWNING ESCAPEMENT OBJECTIVES

Several spawning escapement objectives have been established for different fisheries and stock groups that affect Okanagan summer Chinook.

The CTC (1999) developed an interim escapement goal of 12,143 adult summer Chinook salmon past Rock Island Dam, using PSC Chinook model estimates of escapement and recruitment. A 2008 analysis of actual escapement data resulted in a higher estimate of the spawning escapement that produced the maximum sustained yield, but the CTC requested additional years of data and the CTC has been using the interim escapement goal.

The U.S. management objective for both PFMC and Columbia River fisheries is to regulate harvest of summer Chinook in order to maintain healthy, harvestable natural production and to provide adequate broodstock for artificial enhancement programs. The U.S. v. Oregon parties have adopted an abundance-based spawning escapement objective, based on a minimum requirement of 29,000 adults at the mouth of the Columbia prior to directed harvest (2018-2027 United States v. Oregon Management Agreement); this stock is not managed under PFMC or U.S. v. Oregon to achieve separate objectives for individual watersheds. The U.S. v Oregon objective of 29,000 is interim, and includes a natural escapement objective of 17,000 for all the natural populations, 3,000 for the hatchery programs and 9,000 for expected passage loss [4] between Bonneville and the spawning areas. This escapement objective contains provisions to increase spawning levels when returns are higher than 50,000 adults (Table 1). The increased spawning levels are intended to explore the benefits of higher escapement and test the productive capacity of the spawning areas. The 2018–2027 US v. Oregon Management Agreement calls for reviewing the currently adopted goals.

Since 1998, the Okanagan population has been consistently productive with a long-term (1998-2012) average recruits per spawner of 3.7, with only 2 of 13 years below the 1:1 replacement line (Figure 9). This analysis indicates that the additional escapement has been productive and beneficial.

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[4] The passage loss estimate is a combination of issues caused by different accounting periods at Bonneville Dam and Priest Rapids Dam, imprecision due to overlap in run timing of Snake River spring/summer and Columbia summer, spawners in areas that are not surveyed such as the mainstem Columbia, and actual upstream passage mortalities.

Table 1. Spawning escapement objectives for Upper Columbia summer Chinook, which includes Okanagan Chinook, from the US v Oregon 2018-2027 Management Agreement.

Run Size at River Mouth	Allowed Treaty Harvest	Allowed Non-treaty Harvest
<5,000	5%	<100 Chinook
5,000-<16,000	5%	<200 Chinook
16,000-<29,000	10%	5%
29,000-<32,000	10%	5-6%
32,000- <36,250 (125% of 29,000 goal)	10%	7%
36,250-50,000	50% of total harvestable[1]	50% of total harvestable[1]
>50,000	50% of 75% of margin above 50,000 plus 10,500[2]	50% of 75% of margin above 50,000 plus 10,500[2]

[1] The total number of harvestable fish is defined as the run size minus 29,000 for run sizes of 36,250 to 50,000.

[2] For the purposes of this Agreement, the total number of harvestable fish at run sizes greater than 50,000 is to be determined by the following formula: (0.75 * (runsize-50,000)) + 21,000.

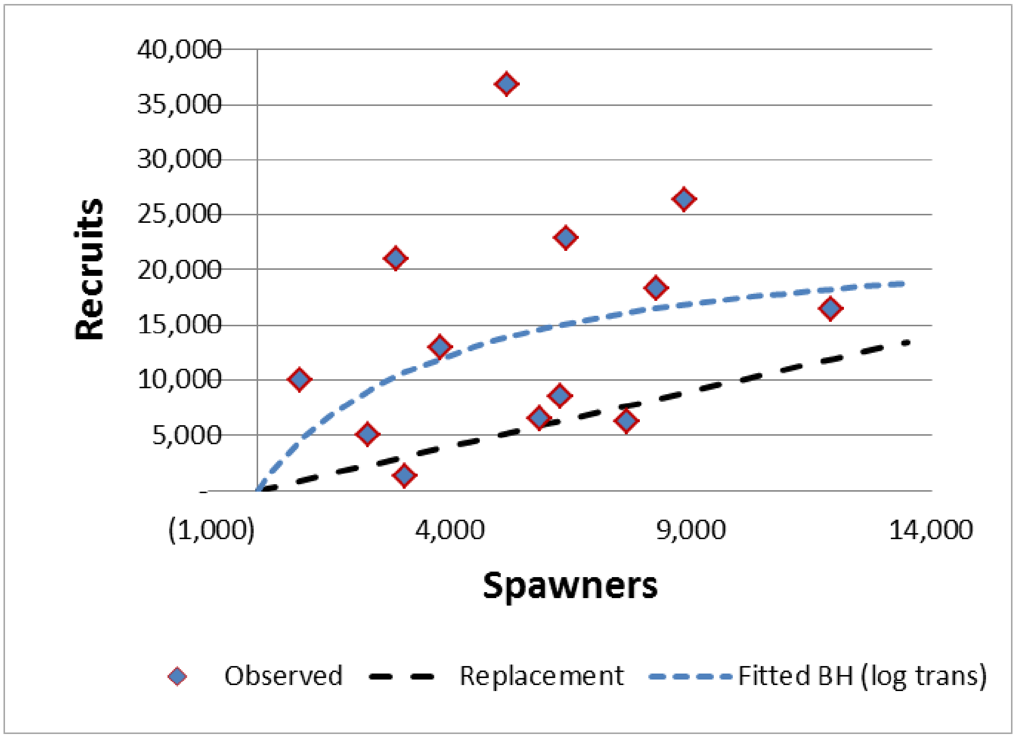


Figure 9. Spawner recruit analysis for summer Chinook in the U.S. Okanagan (and Similkameen) river using the Beverton-Holt (BH) model.

WDFW and the Colville Tribes have agreed to manage fisheries upstream of Priest Rapids Dam to maintain natural spawning escapements upstream of Wells Dam of at least 4,700 adults, with a proportion of hatchery-origin spawners (pHOS) in the Okanagan averaging less than 0.3 and a

Proportionate Natural Influence (PNI) that averages 0.67 or higher (Colville/WDFW Management Agreement 2007; Kamphaus et al. 2015). Since the inception of Chief Joseph Hatchery in 2013, additional analyses, including life cycle modeling, have been used to develop population specific natural-origin escapement objectives that allow the hatchery program to operate at full program while meeting conservation objectives and hatchery reform principles. Although it has not yet been captured in a formal agreement; the current, local escapement objective for natural-origin spawners is 5,250 (7,500 with hatchery-origin spawners). Spawning escapement to the U.S. Okanagan has met the local escapement objectives in approximately half of the years since 2001, when the recent increase in productivity began (Figure 10); the average number of natural origin spawners since 2001 is 4900, slightly below the objective of 5,250.

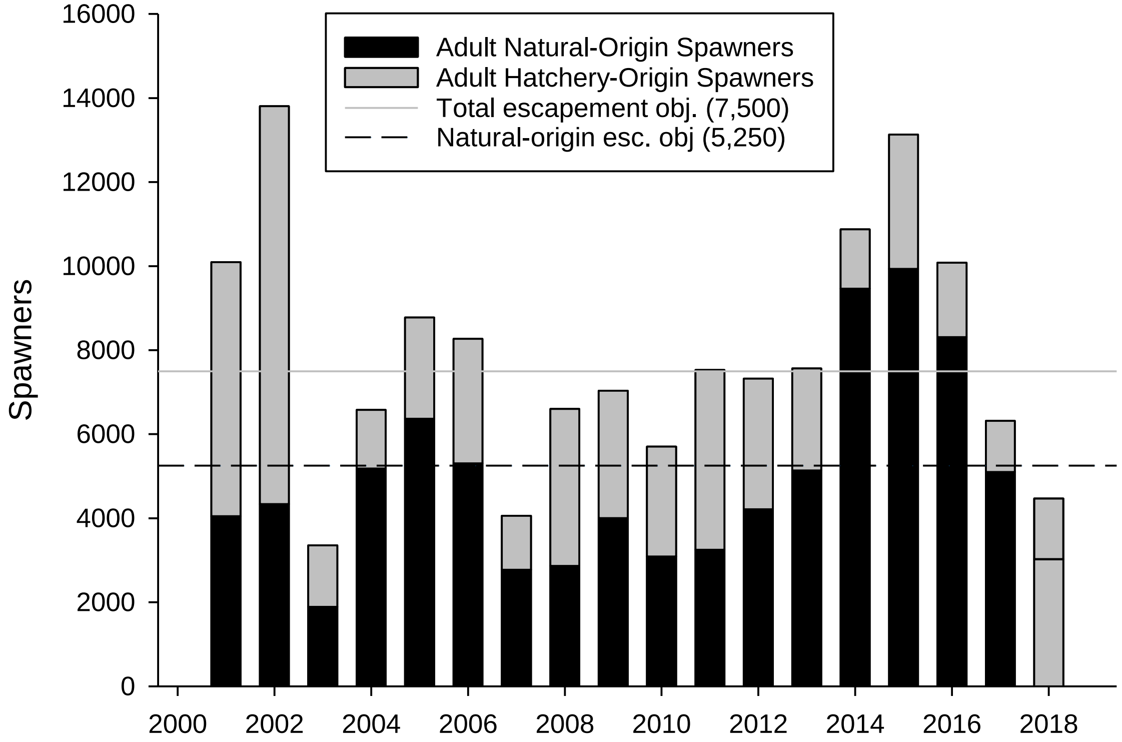


Figure 10. Escapement of natural and hatchery-origin spawners to the U.S. portion of the Okanagan, 2001-2018.

For the Canadian portion of the watershed, a recovery target based on a 4-year geometric mean of 1,000 spawners was identified in the Recovery Potential Assessment report (Mahoney et al. 2019; DFO 2019). This recovery target represents a minimal viable population number for which maintenance of a trend toward positive population growth will be crucial. The recovery target is less than estimates of spawning habitat capacity (ranging from 2,920-8,680 spawners) and a habitat-based estimate of the spawner abundance that would produce the maximum sustained yield (3,400 spawners). As described in other sections (Section 13) of this report, several spawning habitat restoration projects have increased, and are planned to increase, the amount of available spawning habitat.

Canadian Recovery Target

There is now compelling evidence that the loss of genetic variation in small populations is strongly associated with its chance of extirpation. Consequently, in the field of conservation biology, guidelines for minimum viable population (MVP) size have been developed to reduce the rate of loss of genetic variation and sustain breeding populations. While there is an extensive scientific literature on MVP and different species, Bradford and Wood (2004) provide a useful summary of this topic for Pacific salmon and the development of recovery targets for several Canadian conservation units (similar to the U.S. evolutionary significant units).

The Recovery Potential Analysis (RPA, Mahony et. al. 2019) for Canadian Okanagan Chinook salmon recommends a recovery target of 1,000 spawners (based on a 4-year geometric mean) and the need for a positive trend in population growth. While this target is a general conservation guideline not associated with the actual spawners observed in the Canadian Okanagan River, the RPA also notes that “there is no indication that the current availability of spawning habitat would limit the recovery of Okanagan Chinook Salmon at any stage, given the current abundance of observed salmon.” However, the RPA also notes that it is very unlikely that recovery target would be achieved in 12 years (3 generations) under current conditions, unless supplementation of natural spawners was also undertaken (“supplementing the population with hatchery Chinook from the upper Columbia River”). For comparison, estimates of spawning habitat capacity in the Canadian Okanagan range from 2,920-8,680 spawners based on measurements of stream flow, depth and substrate, and an abundance of 3,400 spawners is estimated to produce the maximum sustained yield (Davis et al. 2008).

In the context of the assignment to this working group, Canadian members must respect the advice to government included in the Scientific Advisory Report (Mahony et. al. 2019), but the recovery target does not preclude the development of interim recovery targets developed as part of an integrated recovery program involving the local natural spawners plus a collaborative supplementation program. Further, as a component of a much larger meta-population in the Okanagan River, we note that the much larger abundance in the US side provides a buffer for genetic and demographic risks to the Canadian Okanagan. To restore and maintain a Canadian Okanagan Chinook population, it will be necessary to monitor the contribution of supplemented fish, productivity of Chinook in the Canadian habitats and downstream, and the possible divergence of characteristics over time.

A stock-recruitment analysis was conducted for the Okanagan Chinook for brood years 1998-2012 (Figure 9), however new data and alternate analytical techniques are available to represent its population dynamics and productivity. Specifically, new CWT information is available for the age-specific exploitation and out-of-basin stray rates for the Okanagan Chinook. The Okanagan Chinook CWT information will better represent the exploitation than the CWT data for the Wells Hatchery stock, because there are some important limitations with the Wells hatchery CWT data. These limitations include (1) the use of a mixture of yearling and subyearling tag codes, (2) a younger maturation pattern than the Okanagan stock when only yearling CWT releases were examined, (3) treatment of all harvests upstream of Rocky Reach Dam as escapement, and (4) treatment of CWT recoveries in any of the Columbia Summer Chinook spawning rivers and Wells hatchery as escapement. When data are available for the age-specific abundance of natural origin Chinook spawning in the Okanagan River, it could be helpful to update the stock-recruitment analysis using the Okanagan CWT data and to examine the relative performance of various types of stock-recruitment models (e.g. Ricker, Beverton-Holt) and environmental covariates (e.g. smolt-to-age3 survival). This analysis would help to describe the productive capacity and recent temporal variation in the productivity of the Okanagan Chinook population.

7 OVERVIEW OF ARTIFICIAL ENHANCEMENT PROGRAMS

Artificial production programs associated with summer Chinook in the region began in the early 1900s. Initial production programs consisted of fry releases supplied from hatcheries in the lower Columbia River. Production of summer Chinook through artificial propagation was intermittent in time and place between the early 1900s through the 1940s, and was supported mostly by federal hatchery facilities. Beginning in the late 1960s, hatchery propagation of summer Chinook has taken place at several facilities operated by the state and federal fisheries agencies. The focus of the releases was into the mainstem Columbia River to support harvest. The Okanagan River was the only river system in the region that did not receive any hatchery-produced summer Chinook through the 1980s to the best of the knowledge and investigations of the OWG. Production of summer Chinook for release into the large tributary streams of the upper Columbia River basin, including the Okanagan River, began with the 1989 brood year.

The Similkameen Pond program began in 1989 and through 2012 released an average of 500,000 yearling smolts each year. From 1989 to 2009 the program collected its broodstock from natural origin summer Chinook at Wells Dam, then reared them at Eastbank Hatchery on the Columbia River, followed by over-winter acclimation at the Similkameen Pond. Following hatchery reform principles, the management approach shifted to collecting local broodstock for the program, rather than using a composite of multiple populations collected at Wells Dam. The Colville Tribe developed a method of using a purse seine to collect natural-origin broodstock at the mouth of the Okanagan and from 2010-2017 the program's broodstock has been more than 90% natural-origin fish from the Okanagan. The Similkameen Pond program is now a component of the Chief Joseph Hatchery (CJH) integrated program and the release target is up to 400,000 yearling smolts(generally a 50:50 split between Omak and Similkameen ponds).

The CJH Program consists of four different Chinook Salmon programs releasing up to 2 million summer Chinook smolts to meet conservation and tribal and state harvest objectives and partially fulfill Federal and Public Utility District mitigation obligations for Columbia River Dam impacts to anadromous salmonids. The CJH began operations in 2013 and consists of integrated and segregated summer/fall Chinook, a segregated Spring Chinook program and a reintroduction program for Spring Chinook listed under the Endangered Species Act. The integrated summer/fall Chinook program expanded on, and now incorporates the previous Similkameen Pond program.

The integrated summer/fall Chinook program uses a high proportion of natural-origin broodstock. Management actions maintain a low proportion of hatchery-origin spawners to achieve population objectives for conservation that ensure that the natural environment has most of the influence on local adaptation. The smolt release targets at full program for the integrated program are 800,000 yearling smolts from the Omak and Similkameen acclimation ponds and 300,000 subyearlings from the Omak acclimation pond.

The integrated program is 100% adipose fin clipped and coded-wire tagged with 10,000 PIT tags. The segregated summer/fall Chinook program is intended for harvest and uses primarily first generation returns from the integrated program to minimize multi-generation hatchery affects. The segregated program smolt release goals are 500,000 yearlings and 400,000 subyearlings from the Chief Joseph Hatchery on the Columbia River (upstream of the confluence with the Okanagan River). The segregated program is 100% adipose fin clipped and includes 200,000 coded-wire tags.

8 HARVEST MANAGEMENT

In the U.S., Okanagan summer Chinook are a component of the larger Upper Columbia summer Chinook management unit in the PSC and US v Oregon processes. The Upper Columbia summer Chinook management unit is represented by a long time series of CWT releases from Wells Hatchery. Upper Columbia summer Chinook escapement objectives are expressed as a single unit in the PSC and US v Oregon management processes. Terminal area returns are forecasted for the single management unit. The capability to manage for the components of Columbia summer Chinook has not been developed for the PSC or US v Oregon processes.

More recent CWT data from the Okanagan Chinook provide information on potential differences in spatial distribution, maturation rates and exploitation rates between the overall management unit, as indicated by Wells Hatchery CWTs, and sub-component for the Okanagan River. Additional CWT information can provide insight to refine the development of the Okanagan component of the management unit.

8.1 EXPLOITATION RATE INDICATOR STOCKS

Summer Chinook originating from Wells Hatchery are used as in the exploitation rate indicator stock for upper Columbia summer Chinook in the PSC and PFMC management forums.

The PSC Chinook model uses Wells hatchery tags that are a mix of fingerlings and yearlings a to represent upper Columbia summer Chinook. The total number of yearling and subyearling Wells

Hatchery Chinook with the specific tag codes used by the CTC have been relative stable since the mid 1990s (Figure 11). Tag codes from brood years 1976-1977 (subyearling) and 1984-1986 (yearling) are used to determine base period metrics (i.e. tag codes 631607, 631642, 631762, 631749, 633224, B10310, and 634402).

The Fisheries Regulation Assessment Model (FRAM) uses Wells Hatchery tags that are both a mix of fingerlings and yearlings to represent upper Columbia summer Chinook. Tag codes from brood years 2005 to 2008 are used to determine base period metrics (i.e. tag codes 633298, 633299, 633596, 633385, 633386, 633799, 633871, 633872, 634287, 634390, 634876, 635092, and 635093).

An on-going review of an updated FRAM base period has encountered several factors that do not align with expectations. This includes: missing CWT hatchery escapement, large ocean harvest rates and misalignment of genetic stock compositions. A review is underway and changes to the FRAM model are expected in 2020.

An exploitation rate indicator stock for the Okanagan summer Chinook was developed for this PSC review. Preliminary results of this indicator stock, along with comparisons to the Wells indicator stock, are provided in Appendix B.

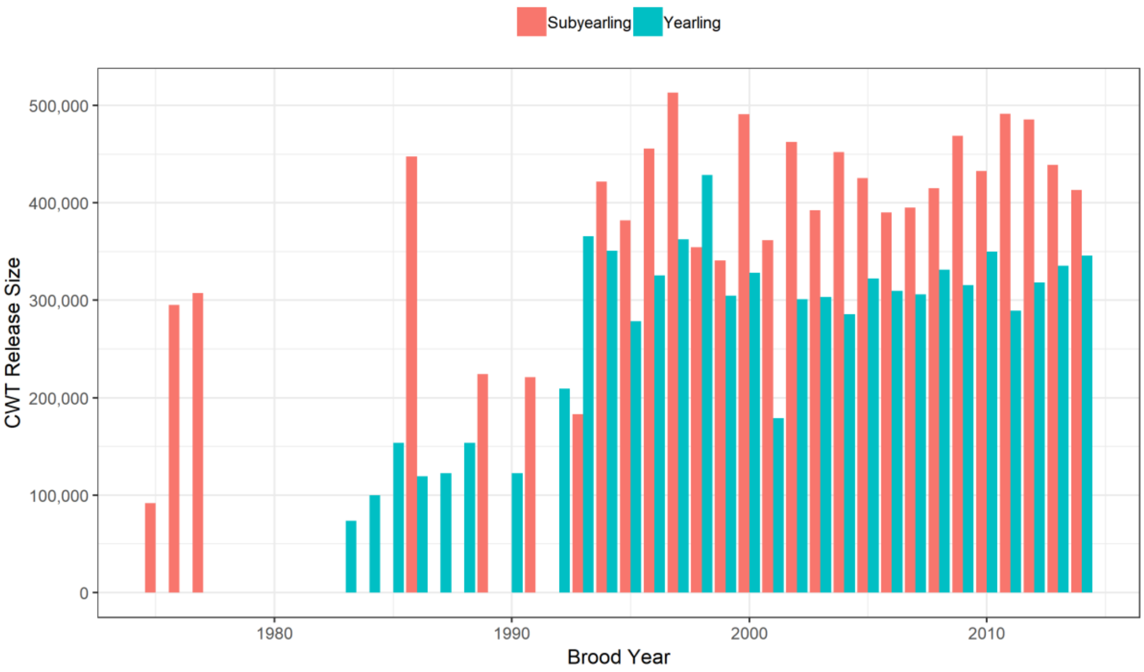


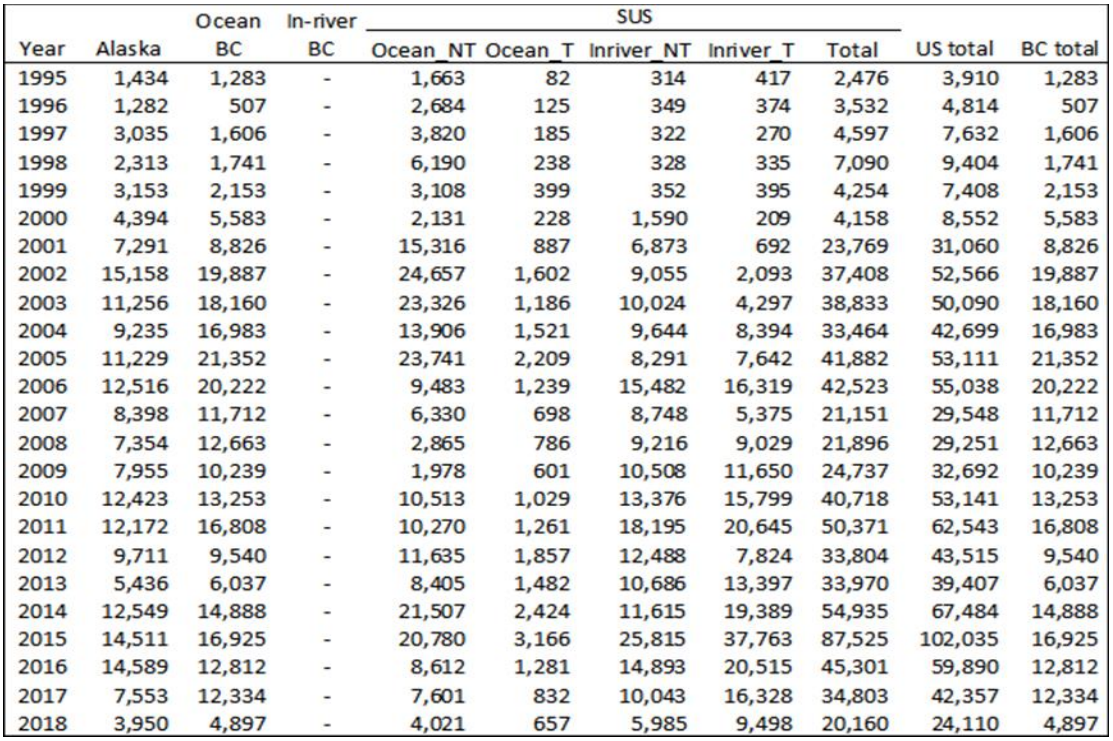
Figure 11. CWT Release sizes by brood year and life history type of all tag codes used by the CTC for the Wells Hatchery summer Chinook indicator stock.

8.2 HARVEST SUMMARY

For Columbia summers, the annual harvest (total mortalities) estimates are provided for FRAM fisheries in Tables 2 and 3, and for Okanagan summers the estimates are provided for major PST fisheries in Table 4. The most recent Columbia River fishery estimates for the summers can be found in the 2019 spring/summer Joint State Staff report (https://wdfw.wa.gov/fishing/management/columbia-river/reports), which includes both *U.S. v. Oregon* treaty and non-treaty fisheries. Harvest year 2002 was the first meaningful year for directed fisheries due to an increasing return of Columbia Summers. The *U.S. v. Oregon* Management Agreement for 2018-2027 has a built-in harvest framework that primarily functions around allocating the harvestable share 50/50 between the treaty (T) and non-treaty (NT; OR/WA in-river and ocean recreational and commercial, Wanapum tribal, and Colville tribal). Except under low run conditions where it reverts to a rate-based approach, the escapement goal is 29,000 to the river mouth with excess being available for harvest except for provisions to increase spawning levels when returns are higher than 50,000 adults (Table 2).

Estimates of the harvest and incidental mortalities of Okanagan Chinook had not been generated among all coast-wide fisheries until the CWT data were analyzed using cohort analysis methods in this report (see Appendix B). Fishery mortalities are highest in the US ISBM fisheries, followed by the US AABM, Canadian AABM and Canadian ISBM fisheries (Table 4). Since 2002, catches of Okanagan Chinook ranged from 2,800 to 10,700, with similar average catches in AABM (3,800) and ISBM (3,700) fisheries based on CWT and escapement data (escapement range: 3,400-13,900). Virtually all Canadian fisheries mortalities occur in marine areas, and there is no directed in river harvest of Chinook in the Canadian Okanagan River, except for very few Chinook harvested by First Nation fishers.

Table *2.* Harvest (total mortality) by fishery of upper Columbia River summer Chinook based on FRAM.



		Ocean	In-river	SUS						
Year	Alaska	BC	BC	Ocean_NT	Ocean_T	Inriver_NT	Inriver_T	Total	US total	BC total
1995	1,434	1,283	-	1,663	82	314	417	2,476	3,910	1,283
1996	1,282	507	-	2,684	125	349	374	3,532	4,814	507
1997	3,035	1,606	-	3,820	185	322	270	4,597	7,632	1,606
1998	2,313	1,741	-	6,190	238	328	335	7,090	9,404	1,741
1999	3,153	2,153	-	3,108	399	352	395	4,254	7,408	2,153
2000	4,394	5,583	-	2,131	228	1,590	209	4,158	8,552	5,583
2001	7,291	8,826	-	15,316	887	6,873	692	23,769	31,060	8,826
2002	15,158	19,887	-	24,657	1,602	9,055	2,093	37,408	52,566	19,887
2003	11,256	18,160	-	23,326	1,186	10,024	4,297	38,833	50,090	18,160
2004	9,235	16,983	-	13,906	1,521	9,644	8,394	33,464	42,699	16,983
2005	11,229	21,352	-	23,741	2,209	8,291	7,642	41,882	53,111	21,352
2006	12,516	20,222	-	9,483	1,239	15,482	16,319	42,523	55,038	20,222
2007	8,398	11,712	-	6,330	698	8,748	5,375	21,151	29,548	11,712
2008	7,354	12,663	-	2,865	786	9,216	9,029	21,896	29,251	12,663
2009	7,955	10,239	-	1,978	601	10,508	11,650	24,737	32,692	10,239
2010	12,423	13,253	-	10,513	1,029	13,376	15,799	40,718	53,141	13,253
2011	12,172	16,808	-	10,270	1,261	18,195	20,645	50,371	62,543	16,808
2012	9,711	9,540	-	11,635	1,857	12,488	7,824	33,804	43,515	9,540
2013	5,436	6,037	-	8,405	1,482	10,686	13,397	33,970	39,407	6,037
2014	12,549	14,888	-	21,507	2,424	11,615	19,389	54,935	67,484	14,888
2015	14,511	16,925	-	20,780	3,166	25,815	37,763	87,525	102,035	16,925
2016	14,589	12,812	-	8,612	1,281	14,893	20,515	45,301	59,890	12,812
2017	7,553	12,334	-	7,601	832	10,043	16,328	34,803	42,357	12,334
2018	3,950	4,897	-	4,021	657	5,985	9,498	20,160	24,110	4,897

Table 3. Estimated catch of upper Columbia summer Chinook by Columbia River fishing area, 1980-2018.

		Zones 1–5. Harvest downstream of Bonneville Dam (BON)					Zone 6 Harvest BON–McNary						
		Non-Treaty (NT)											
Year	Upriver Run[2]	Sport	Comm.	Misc[3]	Treaty	BON Dam Count	NT Sport	Treaty Catch[4]	Zone 6 Escapement[5]	McNary Dam to Priest Rapids Dam (PRD) Sport	Wanapum Tribal (< PRD)	PRD to Grand Coulee Dam Sport	Colville Tribal (>PRD)[6]
80–84	17,505	0	0	51	0	17,453	0	919	16,535	0	0	0	300
85–89	20,982	9	0	75	0	20,900	0	1,170	19,730	0	0	0	300
90–94	14,252	13	0	33	0	14,206	0	165	14,041	0	0	0	300
1995	12,455	14	0	0	0	12,441	0	417	12,024	0	0	0	300
1996	12,080	34	0	15	0	12,031	0	374	11,657	0	0	0	300
1997	17,709	16	0	6	0	17,687	0	270	17,417	0	0	0	300
1998	15,536	27	0	1	0	15,508	0	335	15,173	0	0	0	300
1999	21,867	51	0	1	0	21,815	0	395	21,420	0	0	0	300
2000	22,595	17	0	0	0	22,578	0	209	22,369	0	39	1,092	442
2001	52,960	64	0	1	0	52,895	0	692	52,203	0	82	4,380	2,346
2002	89,524	1,447	0	8	0	88,069	113	2,093	85,863	36	197	4,535	2,720
2003	83,058	1,945	0	36	0	81,077	415	4,297	76,365	40	223	5,187	2,178
2004	65,623	1,246	219	3	0	64,155	260	8,394	55,501	36	157	5,849	1,874
2005	60,272	1,621	2,787	0	0	55,864	423	7,642	47,799	2	338	2,192	928
2006	77,573	4,926	4,819	9	0	67,819	276	16,319	51,224	19	216	3,864	1,353
2007	37,035	2,214	1,122	0	0	33,699	136	5,375	28,188	12	294	3,900	1,070
2008	55,532	2,140	1,370	59	0	51,963	942	9,029	41,992	55	188	2,597	1,865
2009	53,881	2,341	2,524	22	0	48,994	175	11,650	37,169	90	185	2,458	2,713
2010	72,346	2,738	4,720	20	230	64,638	435	15,569	48,634	451	48	2,481	2,484
2011	80,574	5,576	5,004	0	0	69,994	303	20,645	49,046	86	55	5,546	1,626
2012	58,300	3,281	1,692	23	0	53,304	231	7,824	45,249	65	23	3,980	3,194
2013	67,603	2,058	1,954	33	50	63,508	176	13,347	49,985	148	240	2,899	3,178
2014	78,254	2,385	2,743	45	210	72,871	308	19,179	53,384	146	150	2,875	2,963
2015	126,882	6,152	3,938	105	30	116,657	609	37,733	78,315	177	284	4,823	9,728
2016	91,048	3,706	2,990	60	100	84,192	361	20,415	63,416	205	218	4,214	3,140
2017	68,204	3,853	0	47	160	64,144	136	16,168	47,840	126	158	4,325	1,397
2018	42,120	1,140	0	24	50	40,906	12	9,448	31,446	122	68	3,385	1,234
1980's	*19,243*	*4*	*0*	*63*	*0*	*19,177*	*0*	*1,044*	*18,132*	*0*	*0*	*0*	*300*
1990's	*15,650*	*26*	*0*	*9*	*0*	*15,615*	*0*	*326*	*15,289*	*0*	*0*	*0*	*300*
2000's	*59,805*	*1,796*	*1,284*	*14*	*0*	*56,711*	*274*	*6,570*	*49,867*	*29*	*192*	*3,605*	*1,749*
2010's	*76,148*	*3,432*	*2,560*	*40*	*92*	*70,024*	*285*	*17,814*	*51,924*	*170*	*138*	*3,836*	*3,216*
2014-2018	*81,302*	*3,447*	*1,934*	*56*	*110*	*75,754*	*285*	*20,589*	*54,880*	*155*	*176*	*3,924*	*3,693*

Footnotes.

[1] Data source is the 2019 Joint Staff Report: Stock Status and Fisheries for Spring Chinook, Summer Chinook, Sockeye, Steelhead, and Other Species (February 8, 2019).

[2] Includes only adult upper Columbia summer Chinook and reflects current summer management period of Jun 16–Jul 31 to and within the Columbia River. All data has been adjusted. Adjustments may result in data being inconsistent with data found elsewhere in this document. Non-treaty catch includes incidental release mortalities.

[3] Includes incidental non-retention mortality in commercial test, research, American Shad, and sockeye fisheries, and harvest in Select Area fisheries.

[4] Includes commercial and C&S catches.

[5] Bonneville counts minus Zone 6 harvest.

[6] Colville harvest from 1980-1999 has a placeholder estimate of 300 given low level fishing occuring at Chief Joseph Dam and in the Okanogan River. Harvest estimates from 2008 to present are adults only and includes release mortality estimates. Colville Tribal estimates are considered final as Joint State Staff Report estimates may not match.

Table 4. Estimated numbers of Okanagan summer Chinook mortalities in major PST fisheries and escapement. Estimates were generated from Okanagan River escapement and CWT data (Appendix B).

Catch	AABM		ISBM		Escapement	
Year	US	Can	US	Can	Stray	Okanagan River
1993	602	874	433	178	573	1,485
1994	772	646	126	30	1,456	4,033
1995	483	420	42	84	1,044	3,002
1996	154	65	38	21	824	1,819
1997	131	35	26	6	485	2,189
1998	405	80	52	22	513	1,092
1999	472	94	133	5	477	3,617
2000	432	238	134	20	367	3,701
2001	1,432	1,263	1,186	62	385	10,857
2002	2,480	3,981	1,153	22	174	13,857
2003	1,650	2,223	2,022	171	241	3,420
2004	1,708	2,250	2,722	69	83	6,721
2005	2,429	3,767	3,051	56	433	8,889
2006	1,465	2,408	4,030	174	209	8,601
2007	603	625	1,221	115	43	4,417
2008	1,254	755	2,800	49	243	6,975
2009	1,051	1,401	2,950	94	337	7,544
2010	1,258	1,321	3,460	176	176	5,952
2011	1,426	1,426	6,010	114	171	9,681
2012	2,302	2,016	4,675	232	125	8,225
2013	995	1,478	3,673	88	88	8,194
2014	2,254	1,340	4,891	128	213	12,164
2015	1,991	843	6,535	47	94	13,726
2016	3,067	2,172	4,366	149	596	10,605
2017	1,200	1,800	4,705	-	600	10,123

9 POPULATION LIMITING FACTORS

9.1 HYDRO

Chinook salmon returning to the Okanagan River must travel through nine mainstem dams during their migration between the ocean and the river; four of these are federal dams in the mainstem Columbia below the Snake River confluence, whereas the five located upstream of the Snake River confluence are Public Utility District dams, constructed and operated under licenses issued by the Federal Energy Regulatory Commission (FERC).

Chinook smolts leave the Okanagan River and enter Wells Pool, upstream of Wells Dam near Brewster, WA. Wells Dam inundates the lower 14 miles of the Okanagan River, slowing smolt migration and offering additional habitat for predators. However, studies have not been implemented to quantify the effects of predation in the Okanagan River and management actions are not being implemented to reduce predators. These studies may identify a need for predator management programs, such as those found in the Columbia River mainstem that remove Northern Pikeminnow and attempt to reduce Caspian Tern nesting success.

Beginning in the mid-1970s, US fishery managers including state and federal agencies, Columbia River Treaty Tribes, and the Colville Tribes initiated requests to the F FERC for mitigation of impacts to salmonids from the construction and operation of five dams operating with FERC licenses in the mainstem Columbia River (Bodi 1985). The US fishery managers objective was to improve the abundance and productivity of the salmon populations originating upstream of Priest Rapids Dam, including the Okanagan basin. In response, FERC established the Mid-Columbia Proceedings, which incorporated Wells Dam, Rocky Reach Dam, Rock Island Dam, Wanapum Dam and Priest Rapids Dam. The proceedings led to substantial investments by the three Public Utility Districts (PUD) in dam configurations and operations to reduce salmonid mortalities, and in funds to operate hatcheries and improve habitat to mitigate for ongoing mortalities. It established management committees, comprised of the fisheries parties and each PUD, to set mortality standards and mitigation objectives and provide oversight to both the efforts to reduce mortalities and to mitigate unavoidable losses.

The performance standards that began to take effect after 2002 are applied separately for each project, and apply to both downstream passage of juveniles through the reservoir and the dam, and upstream passage of adults through the same geography. The standards are codified in Habitat Conservation Plans (HCP) for Wells, Rocky Reach and Rock Island Dams[5], and in a Settlement Agreement for Wanapum and Priest Rapids Dams[6]. The HCPs are a binding legal obligation under the Endangered Species Act, and the Settlement Agreement was entered as a FERC order. These performance standards were based on a biological assessment of the salmonid populations originating upstream of the Priest Rapids Dam, including the Okanagan watershed (NMFS et al 1998; Table 5), and were established to contribute to the recovery of "at risk" species and to partially compensate for unavoidable losses in the hydro-system. At Wells, Rocky Reach and Rock Island, the survival standard for juvenile sockeye, steelhead and yearling Chinook is 93% (dam and pool). At the Priest Rapids Project (this includes Wanapum, Priest and both pools) the survival standard is 86.49%, which is a combined survival of 93% for each dam and pool.

Table 5. Performance Standards established for the five mid-Columbia Dams.

Combined Juvenile/Adult Survival	Hatchery Mitigation obligation	Habitat Restoration obligation
91%	7%	2%

Under the auspices of the management committees, each PUD has conducted periodic studies to determine actual survivals of yearling outmigrants of Chinook and steelhead as they migrate

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[5] https://www.fisheries.noaa.gov/resource/document/rocky-reach-wells-and-rock-island-mid-columbia-habitat-conservation-plans

[6] https://elibrary.ferc.gov/idmws/doc_info.asp?document_id=4381573

downstream through each project. These studies are used to determine whether these projects are meeting the performance standards. Results to date indicate performance standards are being met for yearlings from all watersheds and production facilities (Skalski and Bickford 2014; Skalski et al. 2012). The parties have had difficulty in measuring survival of subyearling chinook outmigrants, so at this time it remains unclear whether the performance standards are being met for the subyearling portion of the Okanagan summer Chinook population. These studies are designed with a very limited purpose, to measure survival from the upper end of the reservoir to the tailrace of the dam, and are very different than the survival studies being conducted by the Fish Passage Center (FPC) and Comparative Survival Study (CSS) which are designed to measure survival across the entire juvenile migration and from the smolt stage to returning adult. The survival of juvenile Chinook released from Wells Hatchery is monitored regularly through to McNary Dam (Tables 6 and 7), and for juvenile Chinook released from the Okanagan survival has been estimated from release to Rocky Reach, McNary and John Day dams (Table 8). PIT tags are detected at Rocky Reach Dam, McNary Dam, John Day Dam, and Bonneville Dam. However, during the outmigration season for the Okanagan Chinook, there is no detection site downstream of Bonneville (the trawl only operates in the spring) so survivals can be calculated only to John Day Dam using the Cormack-Jolly-Seber method. In 2015 and 2016 the PIT tag detection probabilities in the Lower Columbia River were extremely low, thus survival could only be estimated to McNary Dam. Smolt-to-adult survival rates (SARs) are monitored regularly in the CSS for several Upper Columbia summer Chinook populations (Figures 12 and Tables 8-12).

Table 6. Survivals of subyearling Chinook Salmon released from Wells Hatchery in May between the release location (rel) and McNary Dam (MCN), 2004-2017[7].

Release Date	Migration Year	Survival (rel. to MCN)	95% Confidence Limit	
			Lower	Upper
12-May	2004	0.251	0.205	0.296
18-May	2005	0.341	0.243	0.456
12-May	2006	0.376	0.285	0.478
17-May	2007	0.260	0.189	0.347
13-May	2008	0.371	0.298	0.444
15-May	2009	0.284	0.204	0.364
17-May	2010	0.317	0.241	0.393
19-May	2011	0.527	0.378	0.676
15_May	2012	0.247	0.169	0.324
20-May	2013	0.252	0.181	0.340
16-May	2014	0.257	0.198	0.328
27-May	2015	N/A	N/A	N/A
14-May	2016	0.240	0.144	0.337
24-May	2017	0.220	0.126	0.314

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[7] Data obtained from Chockley, B.R. memorandum to J. Wahls, Jan. 4, 2017. 2016 Wells Hatchery Report. 6p.

Table 7. Survivals of subyearling Chinook Salmon released from Wells Hatchery in June between the release location (rel) and McNary Dam (MCN), 1997-2008[8].

Release Date	Migration Year	Survival	95% Confidence Limit	
		(rel. to MCN)	Lower	Upper
24-June	1997	0.254	0.170	0.338
10-June	1998	0.291	0.241	0.340
19-June	1999	0.373	0.281	0.465
19-June	2000	0.210	0.168	0.253
20-June	2001	0.211	0.166	0.257
17-June	2002	0.449	0.395	0.503
17-June	2003	0.456	0.406	0.506
15-June	2004	0.160	0.106	0.215
13-June	2005	N/A	N/A	N/A
14-June	2006	0.352	0.199	0.534
15-June	2007	0.281	0.155	0.454
16-June	2008	0.294	0.190	0.398

Table 8. Survivals of subyearling Chinook Salmon released in the Okanagan River from the release location (rel) to Rocky Reach Dam(RRE), then to McNary Dam (MCN), and then to John Day Dam (JDA), 2011-2016 (Data from: http://www.fpc.org/documents/CSS/2018%20CSS%20Annual%20Report.pdf).

Migr. Year	Number Released	Rel. to RRE Survival	RRE to MCN Survival	MCN to JDA Survival
2011	13,220	0.45 (0.42 - 0.49)	0.68 (0.60 - 0.77)	0.69 (0.56 - 0.86)
2012	15,276	0.54 (0.49 - 0.60)	0.72 (0.62 - 0.85)	0.78 (0.64 - 0.99)
2013	17,853	0.46 (0.43 - 0.50)	0.82 (0.70 - 0.97)	0.52 (0.41 - 0.66)
2014	8,598	0.37 (0.33 - 0.41)	0.47 (0.37 - 0.67)	0.73 (0.42 - 1.00)
2015	7,787	0.27 (0.20 - 0.40)	NA	NA
2016	14,659	0.24 (0.20 - 0.29)	NA	NA

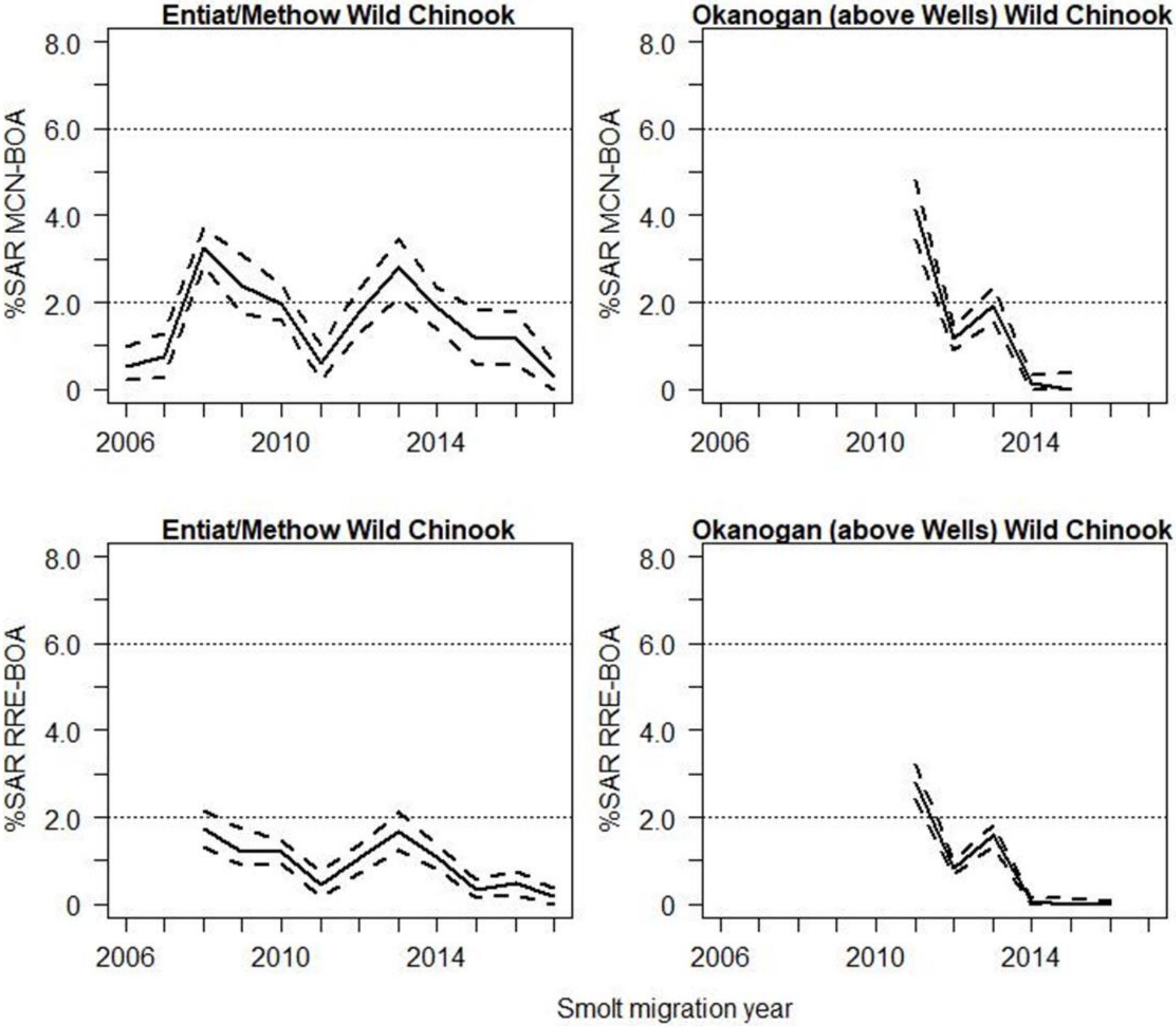

Figure 12. Bootstrapped SAR (MCN-to-BOA and RRE-to-BOA, including jacks) and upper and lower CI for Methow/Entiat wild spring Chinook for migration years 2006–2017 and Okanagan wild summer Chinook for migration years 2011-2017, upper Columbia River region. Migration year 2017 is incomplete with 2-salt returns through June 28, 2019. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference. Data for this figure can be found in Tables B.97 (Entiat/Methow MCN-BOA), B.99 (Entiat/Methow RRE-BOA), B.101 (Okanagan MCN-BOA), and B.103 (Okanagan RRE-BOA). Data from: http://www.fpc.org/documents/CSS/2018%20CSS%20Annual%20Report.pdf.

Table 9. Overall MCN-to-WEA SARs for Upper Columbia Wild Summer Chinook (Okanagan River or Columbia Mainstem above Wells Dam), 2011 to 2016. SARs are calculated with and without jacks. Data from: http://www.fpc.org/documents/CSS/2018%20CSS%20Annual%20Report.pdf.

		MCN-to-WEA (without jacks)			**MCN-to-WEA (with jacks)**		
Juvenile migration year	**Smolts arriving MCN**[A]	**%SAR Estimate**	**Non-parametric CI**		**%SAR Estimate**	**Non-parametric CI**	
			90% LL	**90% UL**		**90% LL**	**90% UL**
2011	4,067	2.75	2.24	3.28	2.83	2.30	3.36
2012	5,946	0.76	0.55	0.98	0.87	0.67	1.12
2013	6,794	1.38	1.07	1.71	1.46	1.13	1.80
2014	1,492	0.13	0.00	0.34	0.13	0.00	0.34
2015[B]	800	0.00	0.00	0.37	0.00	0.00	0.37
2016[C]	---	---	---	---	---	---	---
Arithmetic mean (incl. zeros)		1.00			1.06		
Geometric mean (excl. zeros)		0.78			0.83		

[An] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON and the Logit link.

[B] Due to zero adult returns, 90% confidence intervals are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).

[C] Not calculated, unreliable estimate of release to MCN survival (S1 = 1.0)

Table 10. Overall MCN-to-BOA SARs for Upper Columbia Wild Summer Chinook (Okanagan River or Columbia Mainstem above Wells Dam), 2011 to 2016. SARs are calculated with and without jacks. SARs (with jacks) provided in Figure 12. Data from: http://www.fpc.org/documents/CSS/2018%20CSS%20Annual%20Report.pdf.

		MCN-to-BOA (without jacks)			**MCN-to-BOA (with jacks)**		
			Non-parametric CI			**Non-parametric CI**	
Juvenile migration year	**Smolts arriving MCN[A]**	**%SAR Estimate**	**90% LL**	**90% UL**	**%SAR Estimate**	**90% LL**	**90% UL**
2011	4,067	4.01	3.36	4.66	4.13	3.46	4.81
2012	5,946	1.03	0.78	1.29	1.16	0.90	1.45
2013	6,794	1.81	1.44	2.20	1.91	1.53	2.34
2014	1,492	0.13	0.00	0.34	0.13	0.00	0.34
2015[B]	800	0.00	0.00	0.37	0.00	0.00	0.37
2016[C]	---	---	---	---	---	---	---
Arithmetic mean (incl. zeros)		1.40			1.47		
Geometric mean (excl. zeros)		0.99			1.05		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON and the Logit link.

[B] Due to zero adult returns, 90% confidence intervals are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).

[C] Not calculated, unreliable estimate of release to MCN survival (S1 = 1.0)

Table 11. Overall RRE-to-WEA SARs for Upper Columbia Wild Summer Chinook (Okanagan River or Columbia Mainstem above Wells Dam)[A], 2011 to 2016. SARs are calculated with and without jacks. Data from: http://www.fpc.org/documents/CSS/2018%20CSS%20Annual%20Report.pdf

		RRE-to-WEA (without jacks)			**RRE-to-WEA (with jacks)**		
			Non-parametric CI			**Non-parametric CI**	
Juvenile migration year	**Smolts arriving RRE[B]**	**%SAR Estimate**	**90% LL**	**90% UL**	**%SAR Estimate**	**90% LL**	**90% UL**
2011	5,982	0.74	0.59	0.92	0.84	0.67	1.02
2012	8,207	0.55	0.42	0.69	0.63	0.49	0.78
2013	8,280	1.14	0.92	1.35	1.20	0.97	1.42
2014	3,147	0.06	0.00	0.14	0.06	0.00	0.14
2015[C]	2,065	0.00	0.00	0.14	0.00	0.00	0.14
2016[C,D]	3,485	0.00	0.00	0.09	0.00	0.00	0.09
Arithmetic mean (incl. zeros)		0.42			0.46		
Geometric mean (excl. zeros)		0.41			0.44		

[A] This is the same group as used for the MCN-to-BOA and MCN-to-MCA reaches. SARs are calculated as number of adults at WEA divided by estimated number of smolts at Rocky Reach Dam.

[B] CJS estimation of S1 uses both the juvenile detector and recaptures at Rocky Reach Dam, as well as PIT-tags on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON and the Logit link.

[C] Due to zero adult returns, 90% confidence interval are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).

[D] Incomplete, 3-salt returns through September 15, 2019.

Table 12. Overall RRE-to-BOA SARs for Upper Columbia Wild Summer Chinook (Okanagan River or Columbia Mainstem above Wells Dam)[A], 2011 to 2015. SARs are calculated with and without jacks. SARs (with jacks) provided in Figure 12. Data from: http://www.fpc.org/documents/CSS/2018%20CSS%20Annual%20Report.pdf.

Juvenile migration year	Smolts arriving RRE[B]	RRE-to-BOA (without jacks)			RRE-to-BOA (with jacks)		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2011	5,982	2.72	2.34	3.14	2.81	2.41	3.23
2012	8,207	0.74	0.59	0.92	0.84	0.67	1.02
2013	8,280	1.49	1.24	1.73	1.57	1.30	1.81
2014	3,147	0.06	0.00	0.14	0.06	0.00	0.14
2015[C]	2,065	0.00	0.00	0.14	0.00	0.00	0.14
2016[D]	3,485	0.03	0.00	0.08	0.03	0.00	0.08
Arithmetic mean (incl. zeros)		0.84			0.89		
Geometric mean (excl. zeros)		0.35			0.37		

[A] This is the same group as used for the MCN-to-BOA and MCN-to-MCA reaches. SARs are calculated as number of adults at BOA divided by estimated number of smolts at Rocky Reach Dam.

[B] CJS estimation of S1 uses both the juvenile detector and recaptures at Rocky Reach Dam, as well as PIT-tags on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON and the Logit link.

[C] Due to zero adult returns, 90% confidence interval are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).

[D] Incomplete, 3-salt returns through September 15, 2019.

9.2 HABITAT

Similar to many western rivers, the hydrology of the Okanagan River watershed is characterized by high spring runoff and low flows occurring from late summer through winter. Peak flows coincide with spring rains and melting snowpack (Figure 13). Low flows coincide with minimal summer precipitation, compounded by the reduction of mountain snowpack. Irrigation diversions in the lower valley also contribute to low summer flows. As an example, at the town of Malott, Washington, Okanagan River discharge can fluctuate annually from less than 1,000 cfs to over 30,000 cfs (USGS 2005).

The Okanagan Sub-basin experiences a semi-arid climate, with hot, dry summers and cold winters. Water temperature can exceed 25° C in the summer, and the Okanagan River surface usually freezes during the winter months (Figure 14). Precipitation in the watershed ranges from more than 102 cm in the western mountain region to approximately 20 cm at the confluence of the Okanagan and Columbia Rivers (NOAA 1994). About 50% to 75% of annual precipitation falls as snow during the winter months.

The habitat in the Okanagan watershed has been significantly altered due to agriculture, residential development and road construction. The Okanagan River has high levels of fine sediment and temperatures that routinely exceed species tolerance levels. The portion of these limiting factors that are due to anthropogenic activities is not well understood.

For most of its length, the Okanagan River is a broad, shallow, low gradient channel with relatively homogenous habitat. There are few pools and limited large woody debris. Fine sediment levels and substrate embeddedness are high and large woody debris is rare (Miller et al. 2013). Towns, roads, agricultural fields and residential areas are adjacent to the river through most of the U.S. reaches.

Near its mouth, the Okanagan River is affected by the Wells Dam on the Columbia River, which creates a lentic influence to the lower most 27 km of the Okanagan River. Water level fluctuates frequently because of operational changes (power generation, storage) at Wells Dam.

The Canadian portion of the Okanagan River has been severely impacted by channelization that occurred in the mid-1950s. Only 16% (4.9 km) of the river remains in a natural (2.8 km) or semi-natural state (2.1 km) and 84% (30.4 km) of the river has been channelized, straightened, narrowed and diked. Seventeen Vertical Drop Structures (VDS) were added between Osoyoos Lake and Okanagan Falls to mitigate the resulting increased river slope. Channelization and VDS installation significantly reduced river habitat diversity and function, and greatly reduced diversity and abundance of indigenous species. The channel in the straightened reaches is uniform and provides little spawning habitat for Chinook.

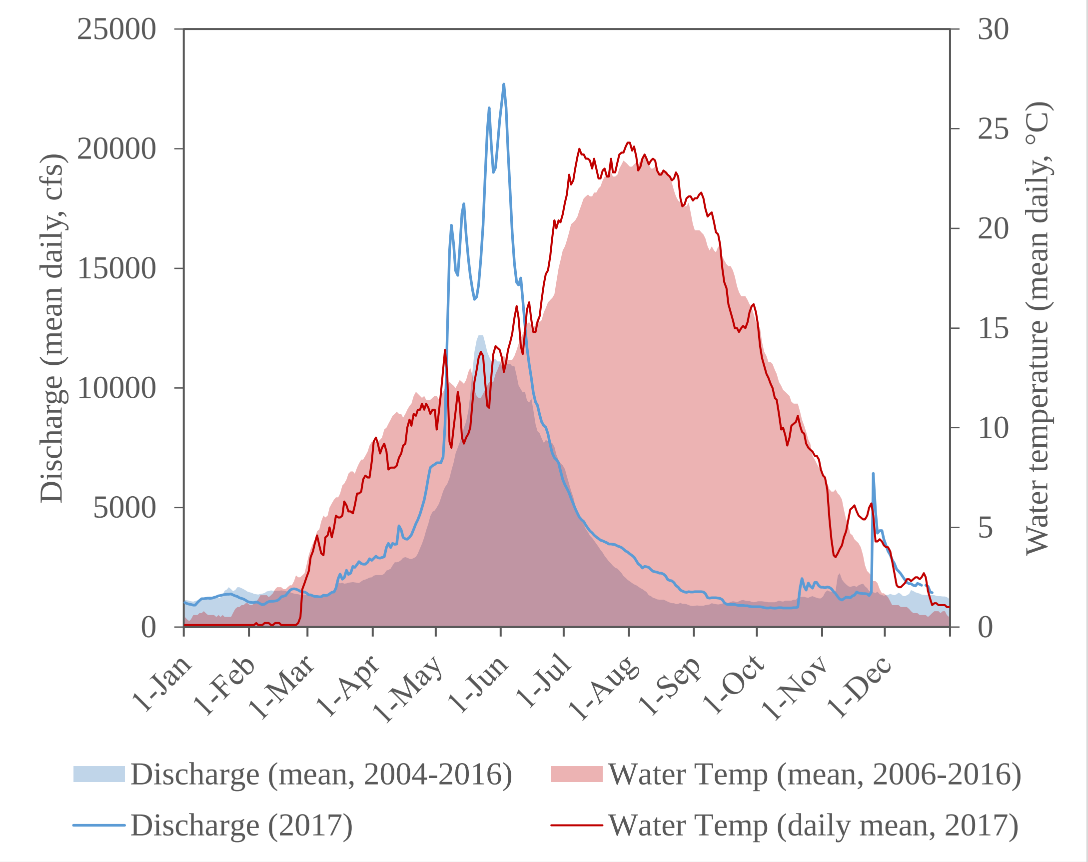

Figure 13. Okanagan River mean daily discharge (blue lines) and water temperature (red lines) at Malott, WA (USGS Stream Gage 12447200).

A thermal barrier forms at the mouth of the Okanagan River when it reaches about 22 C, typically in early to mid-July (Figure 14). The thermal barrier interrupts the migration of Sockeye and Chinook, with some fish migrating through before the barrier sets up and some fish having to hold in the Columbia for up to a month. A second and more severe temperature constraint occurs at the outlet of Lake Osoyoos where warm surface water can exceed lethal temperatures (>26 C) in the Okanagan River (Figure 14). The Similkameen River is cooler and offers an adequate pre-spawn holding environment for Chinook. Several small tributaries with cooler temperatures offer some additional thermal refuge at their confluences with the Okanagan, however, the canyon section of the Similkameen River is the only known major pre-spawn holding habitat.

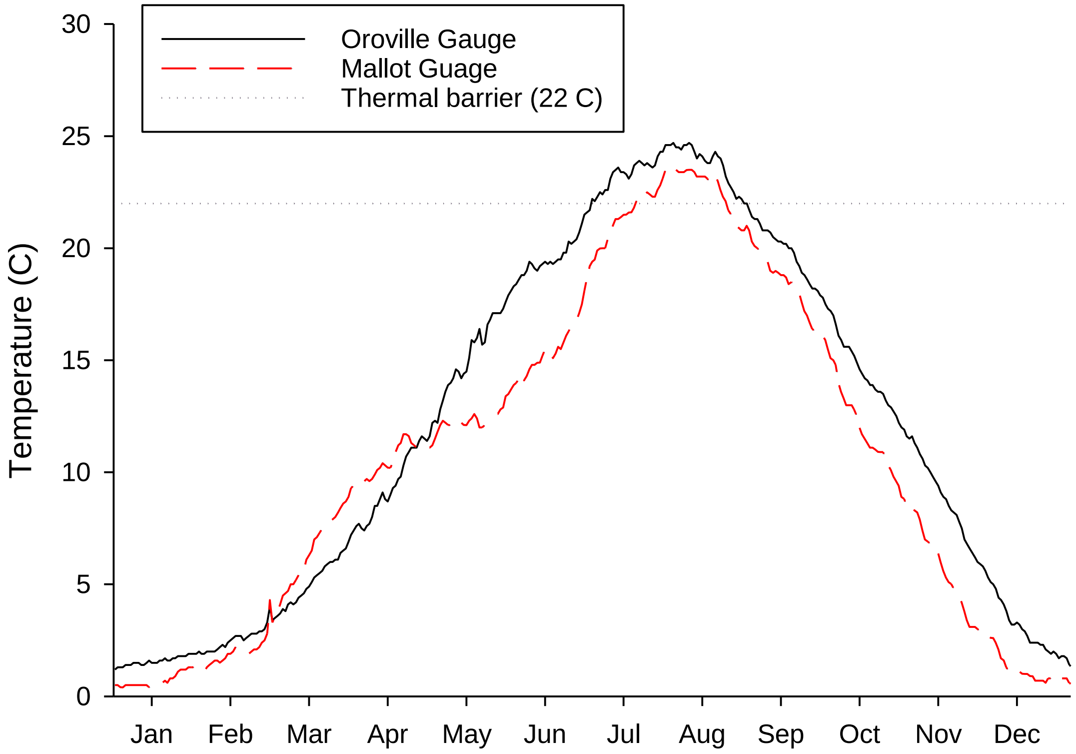

Figure 14. Mean daily temperature from 2007 to 2019 at USGS gauge stations at Mallot (rkm 27) just upstream of Wells Dam pool/Columbia River inundation and at Oroville (rkm 126) just downstream of Zosel Dam and Osoyoos Lake.

9.3 INVASIVE SPECIES

Non-native predators (mostly smallmouth bass) are common throughout the river, but are particularly abundant in the lower Okanagan that is inundated by Wells Pool.

The potential for predation and competition from non-native species in freshwater poses a threat to the productivity of Okanagan Chinook, particularly by affecting the survival of juvenile Chinook. Freshwater non-native species in the Okanagan system include: Yellow Perch, Largemouth Bass, Smallmouth Bass, Pumpkinseed Sunfish, Carp, and Black Crappie which may be either competitors or predators (Hyatt and Stockwell 2019). In addition, Water Milfoil, an invasive aquatic plant, has potentially altered habitat structure to favour invasive fish species relative to indigenous salmonids. Although there is uncertainty as to the specific influences of non-native species on the carrying capacity and survival rates of juvenile Chinook Salmon in rivers, lakes and impoundments, invasive species represent potentially very important threats to the productivity of Okanagan Chinook in Canada and the U.S.

Northern Pike are an emerging, very serious population threat to Okanagan Chinook because they are an apex freshwater predator that, when introduced outside their native range, can impose significant top-down effects on native fish communities through predation and competition for resources (Scott and Crossman 1973, Patankar et al. 2006, Bystrom et al. 2007, Johnson et al. 2008, Spens and Ball 2008, Sandlund et al. 2016). Northern Pike also have relatively wide physiological tolerances allowing them to persist in a range of environmental conditions (Bradford et al. 2008), likely contributing to their expansion into non-native territory. Northern Pike are highly opportunistic predators (Diana 1979; Parken 1996), yet show a strong preference for soft-rayed fusiform fishes including juvenile salmonids (Eklöv and Hamrin 1989; Rutz 1999; Sepulveda et al. 2013), and have been linked to marked reductions in formerly robust Chinook, Coho, and Sockeye Salmon populations in southcentral Alaska following their establishment (Patankar 2006; Haught and von Hippel 2011; Sepulveda et al. 2014, 2015; Smukall 2015; Dunker et al. 2018). The degree of impact from Northern Pike predation to these salmon populations appears to depend largely on habitat-(Sepulveda et al. 2013, 2014), with the greatest reductions in salmon abundance occurring in shallow and vegetated homogenous habitats that lacked spatial refugia for other species (Dunker et al. 2018). Within the Okanagan Basin, these habitats occur in Vaseaux Lake, Osoyoos Lake, and the lower 14 km of the Okanagan River that are inundated by Wells Pool.

Northern Pike have recently (2007) invaded the mainstem Columbia River in both B.C. and Washington, and currently inhabit an approximate 300 km reach between the Hugh L. Keenleyside and Grand Coulee dams, in addition to sections of the Kettle and Spokane river systems (Doutaz 2019). While they are not present in the Okanagan watershed yet, the Lake Roosevelt population continues to expand. A Northern Pike was recently (Nov 2018) captured within 16 km (10 miles) of the Grand Coulee Dam indicating there is a real threat of them continuing to disperse downstream in the Columbia River (Francovich 2018, Pratt 2019). If containment efforts are unsuccessful, it is highly likely that Northern Pike will populate the Okanagan watershed and significantly impede Chinook Salmon restoration efforts as well as reduce the productivity of established populations. Consequently, restoration efforts must address non-native predation through direct management of non-native predators and through habitat restoration efforts such as milfoil control and riparian restoration that reduce habitat quality for non-natives. Management programs designed to prevent the spread of Northern Pike into the Okanagan Basin should be developed.

10 MONITORING AND EVALUATION PROGRAMS

Management agencies have made significant progress on developing monitoring and evaluation programs for Okanagan summer Chinook since Evenson and Talbot (2003) addressed this need.

10.1 OKANAGAN MONITORING AND EVALUATION

The Colville Tribes have an extensive monitoring and evaluation (M&E) program in the Okanagan River Basin that is designed to evaluate natural and hatchery fish performance to support adaptive management of the CJH program and to support ESA recovery for the threatened steelhead population. The CJH M&E program includes tagging (CWT, PIT) to monitor fish survival, recruitment to fisheries, and escapement as well as rotary screw traps and beach seining to provide data on natural-origin smolts. The CJH M&E program operates a weir in the lower Okanagan to collect broodstock and to reduce pHOS in years with abundant hatchery returns in order to protect the natural populations, and to collect other fish biosample data, such as PIT tag recoveries (Figure 15; Pearl et al. 2018). The M&E program also conducts extensive spawning ground surveys to count redds and estimate adult abundance and to collect carcasses to determine spawner age and origin composition and collection of eDNA to assist with understanding distribution, particularly for Spring Chinook. Finally, extensive monitoring also occurs in the hatchery to evaluate life-stage survival and precocity. Habitat status and trend monitoring and steelhead evaluations (juvenile and adult) are implemented through the Okanagan Basin Monitoring and Evaluation Project (OBMEP) and the Broodstock and Monitoring (BAM) project. The OBMEP project includes a high level of coordination and cost sharing between ONA and Colville Tribes, with many identical protocols being implemented on both sides of the border.

The low abundance of Chinook in the Canadian portion of the Okanagan (and limited funding) has made monitoring a challenge. Chinook spawners are counted by ONA during Sockeye enumeration surveys; further details are provided in Section 6.2. The ONA monitors juvenile outmigration using a rotary screw trap located at the outlet to Skaha Lake from late March to early May, and a fyke trap at the Narrows to Osoyoos Lake from late March to early June to monitor juvenile Sockeye Salmon. These sampling sites are upstream of most of the Chinook Salmon spawning habitat, except for the fyke net in the narrows, and therefore is of limited use in acquiring good juvenile abundance data. Regardless, no Chinook Salmon were observed from 2004-2018. Other surveys conducted by the ONA in 2007 using beach seining at Osoyoos Lake found 24 Chinook fry (all caught 7 June). Restoration of Chinook in the Canadian portion of the Okanagan will require an expansion of the monitoring programs to evaluate progress and understand limiting factors and life-stage bottlenecks.

Figure 15. The CJH M&E weir on the Okanagan River downstream of Omak, Washington.

10.2 MAINSTEM COLUMBIA RIVER MONITORING

There is a long history of monitoring anadromous salmonids in the Columbia River and in particular at- and- through the hydroelectric projects. With the advent and expansion of PIT tag use the basin monitoring the movement and survival of juveniles and adults from many release groups has become commonplace. All of the dams include enumeration of adult returns by species through 'window counts' and highly efficient PIT detection in the adult ladders. Most Columbia River dams also include some juvenile PIT detection, with Rocky Reach and McNary dams being key locations for estimating survival. The juvenile bypass facility at Rocky Reach Dam provides a tremendous opportunity to handle and count out migrating smolts from upstream tributaries and hatchery facilities. This facility generally provides enough re-captures to estimate survival from upstream release points and has been a key checkpoint for post-release performance metrics of smolts released from the CJH program.

The 2018 report of the Comparative Survival Study (CSS Oversight Committee and Fish Passage Center 2018) provides estimated Smolt:Adult Recruit survival estimates from Rocky Reach Dam for five recent years. Wild summer Chinook returning to the Okanagan had Smolt-to-Adult-Return rates that averaged 0.69% and exceeded 2% once in the five-year series.

The Okanagan River has a considerable network of PIT Tag interrogation arrays and release sites (Figure 16 and Appendix D Table 1). Most of the interrogation sites occur on tributaries of the Okanagan River, and there are five mainstem interrogation sites. Two releases sites are configured with PIT tag arrays. The five mainstem sites would likely provide the most utility for detecting PIT tagged Okanagan summer Chinook. Of these five sites, two are located in the U.S. portion: one approximately 25 km upstream of the Columbia River confluence which is below the U.S. spawning areas, and one below Zosel Dam which is above the U.S. spawning areas. In Canada, the lowermost site is upstream of Osoyoos Lake (Okanagan Channel at VDS-3 OKC) and below the Canadian spawning areas. This site has been in place the longest since 2009. As fish passage was established, further sites were added at McIntyre Dam (2019) and Penticton Channel which is the current upstream extent of spawning.

Figure 16. Map of PIT Tag Interrogation Sites in the Okanagan River Basin. Map taken from https://www.ptagis.org/sites/map-of-interrogation-sites.

11 MONITORING AND RESEARCH NEEDS

Several monitoring and research needs were identified regarding genetic population structure, stock assessment, and the survival of Okanagan summer Chinook in freshwater and the mechanisms that contribute to their mortality.

11.1 *GENETIC POPULATION STRUCTURE*

Additional research into the meta-population structure of Canadian and U.S. Okanagan Chinook salmon could be helpful to design hatchery supplementation and rebuilding activities. Currently, analyses support the conclusion of a single population across the border, but these analyses involve limited sample sizes that should be increased as part of future monitoring activities. These data would also provide a baseline of genetic information for subsequent monitoring of supplementation and localized population structure. These studies should employ standardized methods and are an essential baseline to initiate immediately.

11.2 *STOCK ASSESSMENT*

Salmon stock assessment often involves monitoring (1) the abundance of spawners relative to an escapement objective, e.g. the spawning escapement that produces the maximum sustained yield (S_{MSY}), (2) the impacts of fisheries, and (3) the factors (biotic and abiotic) that can substantially affect the survival of juveniles and adults.

For spawner escapement programs in Canada and the US, it could be beneficial to examine the accuracy of current escapement estimation programs, and make improvements to them in order to achieve the escapement data quality guidelines used by the PSC CTC (Appendix E in CTC 2013). For example, a PIT mark-recapture, or other approaches, have the potential to produce more accurate and precise estimates of spawners in the U.S. and Canada. Further, a comparison of Chinook counts at Wells Dam and estimates of upstream harvest and spawning escapement indicate that there could be a component of the abundance that is under- or un-represented by the current escapement programs. For example, there may be spawners in the Columbia mainstem that are not surveyed, the abundance of Okanagan spawners may be underestimated, or other factors may be contributing to differences between the estimates, such as fall-back over the Wells Dam. To facilitate comparisons of the Okanagan spawner abundance relative to S_{MSY}, the relationship between spawners and recruitment could be re-evaluated using the newly available CWT exploitation rate data for Okanagan summer Chinook (Appendix B) and age-based estimates of natural and hatchery-origin escapement. This analysis could improve the representation of the population dynamics for Okanagan summer Chinook.

The impacts of fisheries are routinely monitored for Chinook Salmon by the PSC using the CWT Program (Hankin et al. 2005; PSC 2008), and the results of the CWT data analysis contribute to the calibration of the PSC Chinook model (CTC 2018). About 25 years of CWT data were prepared and included in this report, however further work to design and maintain a CWT indicator population for the Okanagan/Similkameen summer Chinook, by incorporating multiple release sites in Canada and the United States, could improve representation of impacts on the natural stock and provide information about stray movements of fish between release and recovery locations. The marking program for this population should incorporate a double index tag group or apply the CTC single index tag methods (CTC 2018) if adult production will be harvested in mark-selective fisheries. The CWT PIT tag data can also be used to back-calculate smolt production indices for different locations in freshwater using the reconstructed CWT cohort abundance data and PIT tag survival estimates. These relative abundance indices can increase knowledge of spawner to smolt population dynamics, and the potential effects of environmental conditions on juvenile survival.

Another valuable research need is the integration of annual monitoring projects for juvenile and adult salmon to provide estimates of annual productivity and temporal variation in Okanagan Chinook salmon (overall and by sub-populations). Substantial variation in productivity has occurred for both the Okanagan and the Columbia summer Chinook over the last 40 years (Figure 2), and a better understanding of the mechanisms that affect productivity, especially those that are manageable, could be beneficial for fisheries and stock rebuilding.

11.3 *SURVIVAL*

Monitoring the survival of Okanagan summer Chinook largely relies on PIT tag and CWT data collected from juvenile and adult fish. The CWT data analysis has provided information about the survival of yearling smolts to age-3 (Appendix B, Figure 3), which is the youngest age that the yearling fish recruit to fisheries and CWTs are sampled. One limitation of the current analysis is that Okanagan natural-origin Chinook have a subyearling life history, but insufficient CWT data are available for the subyearling fish to estimate their survival. Additional CWT marking of subyearling fish could provide additional information about their survival from release to age-2 (i.e. the youngest age when subyearling fish recruit to fisheries) and facilitate comparisons to the yearling fish.

The PIT tag monitoring program in the Okanagan and Columbia rivers provides an exceptional opportunity to gain detailed knowledge about the survival of juvenile Chinook as they migrate downstream through the river and lake segments in the Okanagan basin and also as they migrate by the Columbia River dams. Relatively little information exists about the survival of Chinook smolts migrating through the Canadian sections of the Okanagan, and PIT tagging of fish released in Canada as well as the development of additional PIT arrays around Vaseaux and Osoyoos lakes could provide much needed information about their survival. These areas are a concern because of non-native fish predators (e.g. bass), and the potential roles of river discharge and temperature on Chinook survival. Increased numbers and representation of PIT tagged Okanagan Chinook also enables improved monitoring of their survival during the downstream migration through the Columbia River dams. This information could identify population bottlenecks and inform restoration activities.

Information about the survival of adults on the return migration can also be generated from the PIT tagged Chinook. These fish will be detected at the mainstem dams on the Columbia River and the data can be used to estimate upstream survival and interdam loss. The interdam loss data are used in the CWT cohort analysis. The use of thermal refugia and other holding areas in the Okanagan basin could be monitored when additional PIT tag detection arrays are added in the Similkameen River and when improvements can be made to the detection efficiency of the Zosel Dam array. An improved understanding about the use of different sections of the Okanagan River by adult Chinook could provide helpful information for habitat restoration planning and prioritization. As aforementioned, these PIT tagged adults can also be used by stock assessment mark-recapture programs to estimate spawner abundance. A power analysis would generate the PIT tag sample sizes necessary to achieve precise measurement of juvenile survival rates and the adult mark-recapture population sizes.

Predation on juvenile Chinook Salmon by invasive non-native fishes is one mechanism that likely affects juvenile survival in the Okanagan River system because the warm river temperatures and shallow lacustrine areas are suitable habitat for several predators. However, there is little information available currently about the degree of predation in these areas. In addition to the non-native predators already in the Okanagan, there is considerable concern about the invasion of Northern Pike from the Columbia River, and their potential impact on Chinook and other salmon. Planning can identify approaches to help prevent or reduce the invasion of Northern Pike. A predation monitoring program would help to guide efforts to increase the productivity of Okanagan summer Chinook, and could inform when and where predator control approaches may be appropriate.

The long term impacts of the changing climate and environment on the productivity of Okanagan summer Chinook can be monitored using environmental monitoring information, in combination with adult and juvenile monitoring in the Okanagan system. This information should be examined periodically to identify environmental mechanisms that affect the productivity of Okanagan summer Chinook, and these analyses could contribute to refinement of the fish-water management tool used for the Okanagan basin.

12 HABITAT IMPROVEMENT AND RESTORATION

Within the U.S. portion of the Okanagan watershed, at least 61 restoration projects have been implemented at a cost of about $26 million, most of which were implemented by the Colville Confederated Tribes (CCT) Fish and Wildlife Department using federal hydropower mitigation funding. The majority of those projects occurred in the tributaries with the goal of improving abundance, productivity and spatial structure for ESA-listed steelhead. Projects that likely had the most benefit for summer/fall Chinook include:

- Driscoll Island cross channel structure (2011). Rock structure that keeps summer Chinook redds from desiccating in an important spawning reach.
- Installation of irrigation pump screens (143 screened diversions) (2010-2017)
- Land acquisition/habitat conservation along the mainstem Okanagan River and its floodplain (4 properties; ~200 acres; including some alcoves and off-channel rearing areas)
- Conservancy Island side-channel (improved flow and access to 1/2 mile of side-channel/floodplain and off-channel rearing).
- The emphasis to improve instream flow in the tributaries (for steelhead access and rearing) does provide cool water to the Okanagan River that can be thermal refuge for late migrating juveniles and pre-spawn adult holding (effects not quantified).

In Canada, the health of the Okanagan River has been severely impacted by the channelization works that occurred in the mid 1950s. Only 16% (5 km) of the river remains in a natural (3 km) or semi-natural state (2 km). About 84% (30 km) of the river has been channelized, straightened, narrowed and dyked. In an effort to regain the habitat quality and quantity that has been lost, the Okanagan River Restoration Initiative (ORRI) concept was conceived in 2000. ORRI is an ecosystem based collaborative approach assembling provincial (BC Ministry of Forests, Lands, and Natural Resources Operations), federal (DFO, Environment Canada), First Nations (ONA, CCT, Osoyoos Indian Band, Penticton Indian Band) and various local authorities and funders via a Steering Committee. Based on the late Chief Albert Saddleman vision not only would the river be put back, but the fish would be put back into their traditional territories. Fish passage projects have started from the downstream most points and moved upstream incrementally (Table 13).

Table 13. Fish passage project that have altered available Chinook habitats.

Year	Passage project	Location	Stream length (km)	Cost
2009	McIntyre Dam	Mainstem	7.07	$1, 700,000
2014	Skaha Dam	Mainstem	6.28	$8,000
2014	Shingle Dam (2.2km)	Tributary	35	$250,000
2015	Shuttleworth Basin	Tributary	26.7	$259,000
2018	Ellis basin	Tributary	5	$140,000

To “put the river back”, the ORRI was created to return portions of the channelized river back to more natural conditions. ORRI restoration works near Oliver B.C. include:

- relocating dikes and reconnecting the river to its historic floodplains,
- re-establishing river meanders, lengthening the river channel and re-creating pool/riffle sequences,
- creating nature-like habitat features, such as, spawning beds, rock riffles, side channels, wetland ponds, boulder clusters and gravel bars, and
- replanting riparian vegetation.

Further north in the Penticton channel ORRI re-naturalization goals have been to create spawning areas (raised spawning beds) with optimized gravel size, bed slope and hydraulics for Sockeye, Kokanee and Chinook while enhancing rearing habitat for juvenile salmonids and Burbot with boulder clusters. The long term purpose is to create more complex and diverse habitat for fish and wildlife (multi-species; Figure 16), and several potential project have been identified and or completed (Bull 1999; Table 14).

Other restoration activities focused on improving the management of water within the Okanagan watershed. The Fish Water Management Tool (FWMT) is a web-based computer model that guides Canadian water and fish managers to fish-friendly decisions on water releases from dams in the Canadian Okanagan. The FWMT benefits Chinook by, 1) stabilizing flows during fall spawning, 2) preventing dewatering of eggs during incubation, 3) preventing flows that could scour alevins from redds before spring emergence (Machin et al. 2018).

Figure 17. Example of the ORRI vision to increase complexity back into the river system.

Table 14. Fish and floodplain habitat created via the Okanagan River Restoration Initiative (ORRI) projects.

Habitat created via ORRI		Length /areas		Cost
2008	setback dyke	1,200	m	$1,310,700
	floodplain reconnected	15,000	m^2	
2009	Re-meander	500	m	
	pool-riffle habitat added	11,175	m^2	
	spawning areas	9,100	m^2	
2013	VDS13 modifications – spawning area	4,575	m^2	$146,933
2013	Seasonal side channel reconnection	5,239	m^2	$985,700
2014	wetland features - salamander pond	200	m^2	$87,000
	wetland features - spadefoot pond	60	m^2	
	floodplain - boulder, Woody features	400	m^2	
2014	penticton channel spawning bed 1& 2	7,074	m^2	$455,200
		430	m^2	($38K in kind)
2019	Lougheed floodplain connections and	744	m^2	$12,000

13 OPPORTUNITIES TO ENHANCE PRODUCTIVITY AND ABUNDANCE

In Canada, Chinook habitat restoration planning for coming years include two new projects;

1. Okanagan River Restoration Initiative (ORRI) - VDS Removal for River Habitat Restoration, and
2. k’əmcənitkʷ Floodplain Re-engagement.

Seventeen Vertical Drop Structures (VDS) were added between the US-Canada Border and Okanagan Falls to mitigate the increased river slope following Okanagan River channelization in the 1950s. Channelization and VDS installation significantly reduced river habitat diversity and function, and greatly reduced diversity and abundance of indigenous species. This project addresses one of the VDS between Skaha and Vaseux Lakes. Monitoring in this area indicates (George and Alex 2015):

- fewer salmonids than all other fish combined,
- exotic fish outnumber indigenous fish, and
- overall density of fish is relatively low.

The goal of this restoration is to remove one of the VDSs and create riffle structures which will;

- restore 32,320 m^2 of habitat,
- reduce invasive fish and plant presence, and
- improve public safety, and maintain channel stability and associated infrastructure.

The k'əmcənitkʷ Floodplain Re-engagement is a joint effort among ONA, En'owkin Center, and Penticton Indian Band, with support from many others. It will re-engage 3300m^2 of the Okanagan River's historic floodplain and restore 5,100 m^2 of riparian area on land legally protected in perpetuity for ecological-cultural stewardship. k'əmcənitkʷ Floodplain Re-engagement project is specifically designed to:

- reconnect riparian areas seasonally at spring freshet flows,
- create rearing areas with water depths and habitats suitable for Chinook Salmon, and
- increase complex habitat with logs and boulders, overhanging vegetation from the bank and improve stream-bed substrate with gravel to deter introduced milfoil colonization.

The floodplain re-engagement site in Penticton represents the only remaining continuous piece of floodplain restorable in Penticton without major infrastructure changes, and is the only section of the channel where a refuge pool of significant size and connected to sufficient riparian buffer is possible. The site occurs immediately upstream of an important Spring Chinook spawning tributary, and immediately downstream of a recently restored Summer Chinook spawning area.

Connecting floodplains increases growth rates, survival, and carrying capacity, especially for salmonids including Chinook (Boughton and Pike 2013, Elser 1968, Ericksen et al. 2009, Limm and Marchetti 2009, Sellheim et al. 2015, Sommer et al. 2001, Teel et al. 2009). They also provide high water refuge and invertebrate prey production for native fish, nutrient input, and moderate water temperatures that are documented in the Columbia River mainstem system (Teel et al. 2009).

Hatchery supplementation (enhancement) can contribute substantially to the abundance of Okanagan summer Chinook (Figure 10), and increased hatchery supplementation in Canada could contribute to rebuilding overall abundance (Bussanich 2016, DFO 2019; Mahoney et al. 2019). The recent completion of the Chief Joseph Hatchery, located on the Columbia River near the mouth of the Okanagan, provides an egg-take source that is specific to the Okanagan watershed. Recently, some eggs have been transferred from the Chief Joseph Hatchery to the kł cp̓əlk̓ stim̓ Hatchery in Penticton, B.C., and released into the Okanagan River in Canada. Currently, the kł cp̓əlk̓ stim̓ Hatchery has the capacity to produce more Okanagan summer Chinook. However, there can be challenges with collecting sufficient eggs by the Chief Joseph program to meet the objectives of the U.S. supplementation program. Other types of egg-take approaches, such as stream-side collection from the Okanagan and Similkameen rivers, near Oroville, WA, could provide more eggs to be reared at the Penticton hatchery. The Okanagan Nation Alliance fisheries program uses the stream-side egg-take approach for the enhancement of Okanagan sockeye.

14 RECOMMENDATIONS

The work group identified four main recommendations to the Commission:

1. Establish a bilateral advisory and science committee to aid in the development of supplementation, monitoring, and future research programs. This committee would provide an annual report to the Pacific Salmon Commission (Chinook Interface Group).
    a. Given the complex structure of Mid-Columbia River summer Chinook in the US and the recent recalibration of the CTC Chinook model, in the immediate term, the proposed restoration and monitoring of the Okanagan Chinook can be tracked separately and reported to the Commission.
    b. Future consideration of the Canadian Okanagan summer Chinook within the PST will require development and agreement on biologically-based management objectives.
    c. Separation of the Mid-Columbia River summer Chinook stock group into separate population units would require significant consultations and analysis, and is unlikely to be implemented within the term of the present Agreement.
2. Establish an annual supplementation program based on the current, successful efforts and utilizing hatchery facilities in both countries. This program would provide adult returns to habitats restored in the Canadian Okanagan and would provide fish to study survival of these out-planted juveniles through the Canadian lakes and altered stream sections (both countries presently utilize PIT tags for similar studies).
3. Establish a bi-lateral monitoring program to support and evaluate restoration efforts and incorporate survival rate studies of tagged summer Chinook and predator studies. Key objectives of the monitoring program would be to identify the limiting factors to production of summer Chinook in the Okanagan and Similkameen rivers, and development of a joint genetic monitoring program to further understand the population structure of Okanagan summer Chinook salmon, and the possible divergence of naturally-spawning Chinook in the Canadian Okanagan River.
4. Develop and implement a plan to prevent the spread of Northern Pike into the Okanagan watershed, and address existing predation issues as identified by the above studies.

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APPENDIX A: MID-COLUMBIA HATCHERY PROGRAMS

Table 1: Hatchery programs in the mid-Columbia River Basin, 2014-2023 releases (combination of NNI and inundation obligations and new production at the new Chief Joe Hatchery). Funding entities include Douglas PUD (D), Chelan PUD (C), Grant PUD (G), Bonneville Power Administration (B), Bureau of Reclamation (O), and Army Corps of Engineers (A). Total artificial production targets in the mid-Columbia River exceeds 15 million juveniles annually (this does not include an additional 5.2 million sub-yearling fall Chinook produced and released into the Hanford Reach at Priest Rapids and Ringold Springs Hatchery as part of the Army Corps of Engineers production obligation).

Program	**Species**	**Basin**	**Purpose**	**Funding Entity**	**2014-2023 NNI and New Production**	**Pre-Recalc. Production**
Methow	Spring Chinook [1]	Methow	NNI/Conservation	Chelan	60,516	
				Douglas	29,123	
				Grant	134,126	
				Subtotal	*223,765*	550,000
Chief Joseph	Spring Chinook	Okanagan	Reintroduction/Harvest	BPA	641,700	
				Chelan	115,000	
				Douglas	33,300	
				Grant	110,000	
				Subtotal	*900,000*	NA
Chiwawa	Spring Chinook [1]	Wenatchee	NNI/Conservation	C	144,026	298,000
White	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	74,556	150,000
Nason	Spring Chinook [1]	Wenatchee	NNI/Conservation	G	149,114	250,000
Winthrop	Spring Chinook [2]	Methow	Safety-Net	O	400,000	600,000
Leavenworth	Spring Chinook [2]	Wenatchee	Harvest	O	1,200,000	1,200,000
Wells	Steelhead [1]	Columbia	Inundation/Safety-Net	D	160,000	NA
Winthrop	Steelhead [1]	Methow	Conservation	O	200,000	100,000
Wells	Steelhead [1]	Methow	Inundation/Safety-Net	D	100,000	300,000
Wells/Omak	Steelhead [1]	Okanagan	NNI/Conservation	G	100,000	100,000
Wells	Steelhead [1]	Twisp	Inundation/Conservation	D	40,000	
Wells	Steelhead [1]	Twisp	NNI/Conservation	D	8,000	48,000
Chiwawa	Steelhead [1]	Wenatchee	NNI/Conservation	C	22,000	235,000
Chiwawa	Steelhead [1]	Wenatchee	Inundation/Harvest	C	165,000	165,000
Chiwawa	Steelhead [1]	Wenatchee	Species trade	C	60,300[5]	NA

Program	Species	Basin	Purpose	Funding Entity	2014-2023 NNI and New Production	Pre-Recalc. Production
Wells	Summer Chinook [2, 3]	Columbia	Inundation/Harvest	D	484,000	484,000
Chief Joseph	Summer Chinook [3]	Okanagan	NNI/Supplementation	BPA	556,430	
				Chelan	94,570	
				Douglas	49,000	
				Subtotal	*700,000*	NA
Chelan Falls	Summer Chinook [2]	Chelan	Inundation/Harvest	C	400,000	400,000
Chelan Falls	Summer Chinook [2]	Chelan	NNI/Conservation	C	176,000	200,000
Wells	Summer Chinook [2]	Columbia	Inundation/Harvest	D	320,000	320,000
Entiat	Summer Chinook	Entiat	Harvest	O	400,000	400,000
Carlton	Summer Chinook	Methow	NNI/Supplementation	G	200,000	400,000
Chief Joseph	Summer Chinook	Okanagan	NNI/Supplementation	BPA	807,331	
				Chelan	166,569	
				Douglas	48,100	
				Grant	278,000	
				Subtotal	*1,300,000*	576,000[7]
Dryden	Summer Chinook	Wenatchee	NNI/Supplementation	Chelan	318,815	
				Grant	181,816	
				Subtotal	*500,000*	864,000
Priest	Fall Chinook[3]	Columbia	Inundation/Harvest	G	5,000,000	5,000,000
Priest	Fall Chinook[3]	Columbia	NNI/Harvest	G	325,543[6]	1,000,000[6]
Priest	Fall Chinook[4]	Columbia	Fry loss/Harvest	G	273,961[6]	1,000,000[6]
Methow	Coho	Methow		B,G,C,D	500,000[8]	500,000
Wenatchee	Coho	Wenatchee		B,G,C,D	1,000,000	1,000,000
Wenatchee	Sockeye	Wenatchee	NNI/Supplementation	C	Species Trade[5]	200,000
Okanagan	Sockeye	Okanagan	NNI/Supplementation	D	NNI achieved by funding a fish-water management tool in Canada	
Skaha	Sockeye	Okanagan	NNI/Supplementation	C,G	NNI achieved by funding Skaha reintroduction program	

Program	Species	Basin	Purpose	Funding Entity	2014-2023 NNI and New Production	Pre-Recalc. Production
Spring Chinook Sub-total					**3,091,461**	**3,048,000**
Steelhead Sub-total					**855,300**	**948,000**
Summer Chinook Sub-total					**4,480,001**	**3,644,000**
Fall Chinook Sub-total					**5,599,504**	**7,000,000**
Coho Sub-total					**1,500,000**	**1,500,000**
Sockeye Sub-total					**0**	**200,000**
Grand Total					**15,526,266**	**16,340,000**

[1] Species listed under the Endangered Species Act.

[2] Segregated program.

[3] Sub-yearling production.

[4] Fry production as required by the Priest Rapids Settlement Agreement (section 9.5). In 2013 the signatories agreed to convert the 1M fry program to a 273,961 sub-yearling smolt program. This is fixed mitigation and not part of the NNI process.

[5] Species trade consists of converting 46K NNI sockeye production (size of program after recalculation) to steelhead plus an additional 14,300 steelhead to maintain steelhead production at Chiwawa Ponds consistent with the overwinter capacity of 247,300 smolts.

[6] Smolt and fry production that per the Settlement Agreement, would not be implemented until completion of the Priest Rapids rebuild. Adults for this production were collected in 2013.

[7] The 576K pre-recalculation production was Chelan PUD mitigation for the Okanagan River, met through using Eastbank FH and Similkameen Rearing Pond. With construction of CJH, the PUD entered into agreements with the CCT to have this production fulfilled at their facility.

[8] Coho production in the Methow is expected to go up to 1M beginning with the 2015 brood.

APPENDIX B: DEVELOPMENT OF OKANAGAN INDICATOR STOCK

Background

An Exploitation Rate Analysis (ERA) was conducted for yearling summer Chinook Coded Wire Tags (CWT) released into the Okanagan and Similkameen rivers. An ERA is a cohort analysis technique developed by the Chinook Technical Committee (CTC) and is annually conducted for several different indicator stocks. Cohort analysis simply reconstructs the production of a group of CWTs by starting with the escapement, catch, and incidental fishing mortality of the oldest age class, working backwards in time to calculate the total abundance of the youngest age Chinook in the ocean prior to any fishing-related mortality. These reconstructions are based on estimated CWT recoveries by stock, brood year, and age in fisheries and escapements.

Once the cohort reconstruction is complete, several different metrics that form the basis of the ERA can be calculated. This analysis examined release to age-3 survival, maturation rates and the distribution of total mortality. The Annual Exploitation Rate Analysis and Model Calibration Report produced by the CTC (e.g. CTC 2018) includes additional summaries along with methodological descriptions. Please reference CTC 2018 for a more thorough description of the metrics reported here.

When reporting ERA metrics for Okanagan yearling summer Chinook, specific comparisons are made to yearling summer Chinook from Wells Hatchery. Currently, the CTC uses a mix of subyearling and yearling Chinook CWTs from Wells Hatchery as an indicator for the Upper Columbia summer Chinook stock aggregate. Only yearling CWTs from Wells Hatchery yearlings are used in this report for more direct comparisons to the yearling Okanagan summer Chinook. Comparisons of ERA metrics between stocks are made in order to assess whether Okanagan summer Chinook exhibit different life history characteristics than the current indicator stock used by the CTC. Simple statistical tests of similarity between stocks are reported.

Coded Wire Tags Used in the Exploitation Rate Analysis

Prior to conducting the cohort reconstruction, a list of CWT codes that could be used needed to be determined. A candidate list of tag codes was determined with a basic Regional Mark Information System (RMIS) query. Subsequently, an examination of the number of recoveries per tag code and expert opinion was used to determine a final list of tag codes.

The candidate list of tag codes was determined by first determining all CWT summer Chinook release locations in the Okanagan Basin. This was done by examining all RMIS release location names with RMIS basin equal to “MEOK” and species–run equal to “summer–Chinook”. The release location names resulting from this query that were within the Okanagan Basin were: "BONAPARTE CR 49.0246", "OKANAGAN R 49.0019", "OMAK CR 49.0138", "OMAK POND", "SIMILKAMEEN POND" and "SIMILKAMEEN R 490325". From these release location names, all possible yearling summer Chinook CWT releases were then determined (Table 1). Note, that subyearling summer Chinook CWT releases were not considered for this analysis as this would require another separate ERA. The conclusions that could be drawn from this ERA would be limited since subyearling releases at Omak Pond have only occurred from broods starting in 2013 (results not shown).

Table 1. Candidate list of yearling Okanagan summer Chinook Coded Wire Tag (CWT) codes to use for the Exploitation Rate Analysis (ERA). The "Excluded?" column indicates a "Yes" whenever a CWT code was excluded and a blank cell indicates that the CWT code was included.

Brood Year	Release Location	Tag Code	CWT Release Size	Excluded?
1989	SIMILKAMEEN POND	630759	116,821	
1989	SIMILKAMEEN POND	635613	85,304	
1990	SIMILKAMEEN POND	634417	367,207	
1991	SIMILKAMEEN POND	634604	360,380	
1992	SIMILKAMEEN POND	635148	124,751	
1992	SIMILKAMEEN POND	635154	133,923	
1992	SIMILKAMEEN POND	635155	132,213	
1992	SIMILKAMEEN POND	635156	16,729	
1992	SIMILKAMEEN POND	635315	129,574	
1993	SIMILKAMEEN POND	635706	180,115	
1993	SIMILKAMEEN POND	635708	191,059	
1994	SIMILKAMEEN POND	635762	212,443	
1995	SIMILKAMEEN POND	635534	180,813	
1995	SIMILKAMEEN POND	635536	181,497	
1995	SIMILKAMEEN POND	636051	206,736	
1996	SIMILKAMEEN POND	630136	178,037	Yes
1996	SIMILKAMEEN POND	630218	149,475	Yes
1996	SIMILKAMEEN POND	630220	148,523	Yes
1997	SIMILKAMEEN POND	630610	558,351	
1998	--	--	--	
1999	SIMILKAMEEN POND	630469	583,317	
2000	SIMILKAMEEN POND	630996	525,923	
2001	SIMILKAMEEN POND	631550	26,059	Yes
2002	BONAPARTE POND	631868	9,900	Yes
2002	SIMILKAMEEN POND	631978	244,792	

Brood Year	Release Location	Tag Code	CWT Release Size	Excluded?
2003	SIMILKAMEEN POND	632579	574,908	
2004	SIMILKAMEEN POND	633168	286,106	
2004	SIMILKAMEEN POND	633169	282,476	
2005	BONAPARTE POND	633474	49	Yes
2005	SIMILKAMEEN POND	633594	272,123	
2006	SIMILKAMEEN POND	633972	94,884	
2006	SIMILKAMEEN POND	634182	501,849	
2007	SIMILKAMEEN POND	633475	104,016	
2007	SIMILKAMEEN POND	634365	98,664	
2007	SIMILKAMEEN POND	634366	108,712	
2007	BONAPARTE POND	634367	101,903	Yes
2007	SIMILKAMEEN POND	634392	193,541	
2008	BONAPARTE POND	634777	175,080	Yes
2008	BONAPARTE POND	634783	87,864	Yes
2008	SIMILKAMEEN POND	634875	340,501	
2009	BONAPARTE POND	635365	151,076	Yes
2009	SIMILKAMEEN POND	635371	254,651	
2009	SIMILKAMEEN POND	635579	265,152	
2010	SIMILKAMEEN POND	635582	41,106	
2010	SIMILKAMEEN POND	635690	202,655	
2010	SIMILKAMEEN POND	635691	190,821	
2010	SIMILKAMEEN POND	635968	169,278	
2011	SIMILKAMEEN POND	635680	206,700	
2011	SIMILKAMEEN POND	636173	209,118	
2011	SIMILKAMEEN POND	636174	207,049	
2012	OMAK POND	636181	21,513	
2012	OMAK POND	636182	22,572	

Brood Year	Release Location	Tag Code	CWT Release Size	Excluded?
2012	SIMILKAMEEN POND	636293	112,895	
2013	OMAK POND	200111	127,132	
2013	OMAK POND	200112	127,885	
2013	SIMILKAMEEN POND	200113	98,163	
2013	SIMILKAMEEN POND	200114	81,953	
2014	SIMILKAMEEN POND	200118	147,476	
2014	SIMILKAMEEN POND	200119	36,869	
2014	OMAK POND	200120	213,508	

All tag codes from the 1996 brood year were excluded due to very few recoveries that would potentially result in inaccurate estimates of ERA metrics. Of the 1996 tag codes, code 630136 had only 4 observed recoveries, code 630218 had 0 observed recoveries and code 630200 had 3 observed recoveries. There were disease issues associated with the 2001 brood (Charlie Snow, WDFW, personal communication) that resulted in a small release size. Given that release size of the 2001 brood was approximately 26,000 individuals and that this group was potentially unrepresentative of the run at large due to residual effects of disease after release, this tag code was also excluded from the analysis. Tag code 633474 from the 2005 brood was also excluded from the analysis given the unusually small release size of 49 individuals. However, this code could have been included in the analysis since releases within a single brood year are pooled when conducting the ERA. This also explains why other tag codes with small release sizes (e.g. 635156 from brood year 1992) is not problematic since this data is pooled with other releases from the same brood.

It is possible to pool CWTs from different release ponds within a brood year in the ERA. However, this could be problematic if there are differences in life history characteristics for individuals released from different ponds. A preliminary analysis indicated that release to age 3 survival estimates were different for fish released from Bonaparte Pond compared to Similkameen Pond. Bonaparte release to age 3 survival estimates were 0.011, 0.029 and 0.029 during migration years 2009, 2010 and 2011. Similkameen release to age 3 survival estimates were 0.025, 0.093 and 0.041 during the same set of years. The differences in survival can potentially be explained by release site quality resulting in differences in fish condition. The Bonaparte Pond was an irrigation settling pond that was later adapted and converted into a fish acclimation site, whereas the Similkameen Pond is a modern acclimation facility. Given the differences in survival and releases sites, CWTs released from the Bonaparte Pond from brood years 2002, 2005 and 2007-2009 were excluded. Due to few recoveries and incomplete returns from broods 2012-2014, a comparative analysis of Omak and Similkameen released fish was not feasible. However, differences should be minimal for Omak and Similkameen pond releases because they came from the same brood stock, were both reared for their first year at Chief Joseph Hatchery and transferred to their respective acclimation pond in October. Releases from the Omak and Similkameen ponds from the same brood were pooled in this analysis. This decision will need to be reconsidered when returns from the 2012-2014 broods are completed.

The CWTs to use in the ERA from Wells Hatchery are determined annually by the CTC. The yearling tag codes from this list were taken and used for comparative purposes in this analysis. Figure 1 shows the CWT release size by brood year for yearling summer Chinook from Wells Hatchery and the final yearling Okanagan summer Chinook tag codes. Consistent CWT releases for both stocks did not begin annually until brood year 1992. There were no suitable yearling Okanagan CWT releases from brood year 1996, 1998 and 2001 and so comparisons are not possible for these broods. Figure 1 only shows data up until brood year 2014 because the Southern US lags two years behind in their CWT reporting (i.e. only CWT recoveries up until 2017 can be used) and it is expected that there would be age 3 recoveries from the 2014 brood in 2017. Additionally, the total number of yearling Okanagan summer Chinook CWTs is generally greater than the yearling Wells total for each brood.

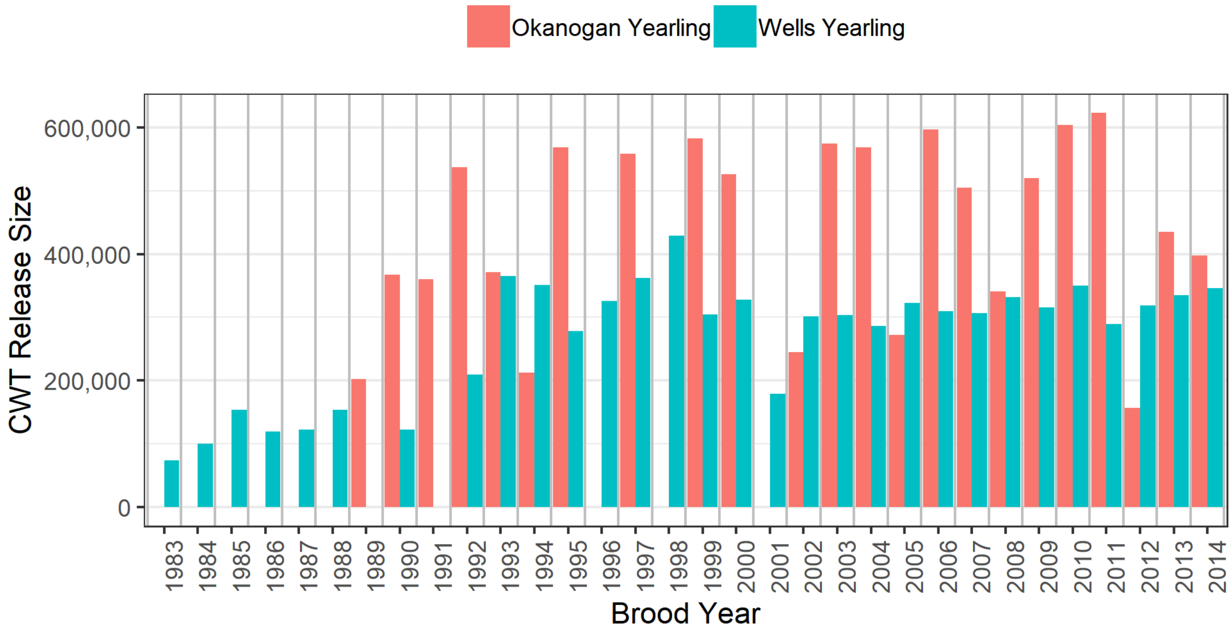

Figure 1. Coded Wire Tag release size by brood year and stock. The total release sizes were determined by the final list of tag codes filtered from the initial candidate list of tag codes.

Inter-dam Loss Estimate

An estimate of inter-dam loss (IDL) is required to determine terminal run (and prior ocean cohort sizes) when reconstructing the CWT cohort from escapement (terminal run = escapement/IDL + terminal harvest). The IDL estimate can be thought of as pre-spawning survival of the unharvested returning adult fish. The IDL is calculated as a ratio of the upstream dam count divided by the downstream dam count minus known removals of fish due to: harvest, escapement to tributaries and brood stock collection. Theoretically, these estimates should be less than one, but in reality, estimates are quite often greater than one due to errors in counts at dams, fallback and reascension, errors in harvest estimates and other sources of uncertainty. The IDL values were constrained to one, and the estimate between multiple dams was calculated as the product of each reach specific IDL.

The IDL survival estimates from Bonneville to Rock Island and from Bonneville to Wells were calculated from return years 1992 to 2017 (Figure 2). Reach-specific IDL estimates are provided in Table 2. The Bonneville to McNary estimate excluded fishery catches occurring in this reach, and was based on McNary dam counts from 9 June to 8 August (not adjusted to remove Snake spring/summer returns). The McNary to Priest Rapids estimate excluded fish counted at Snake River dams, Hanford sport catches, and Wanapum tribal catches. The Priest Rapids to Rock Island estimate excluded all sport catches above Priest Rapids. This involved assuming all of the sport catch from above Priest Rapids Dam (PRD) was in the PRD to Rock Island reach, which is not entirely accurate. The Rock Island to Rocky Reach estimate excluded Wenatchee River escapement estimates and Eastbank Hatchery brood stock collection. The Rocky Reach to Wells survival excluded Entiat and Chelan escapements and Wells Hatchery brood stock collection.

The IDL estimates could potentially be more accurately estimated by using a combination of PIT tags and in-river harvest rate estimates. This would involve estimating a reach survival estimate from Bonneville to Rock Island (or Wells Dam) and expanding that estimate by one minus the harvest rate for the entire reach. This estimate would still include uncertainty in harvest accounting, but would eliminate inaccuracies in dam counts given that PIT tag detection probabilities at dams are nearly 1. The CTC should consider exploring the possibility of PIT tag derived IDL estimates for all Columbia River stocks originating above Bonneville Dam.

It is worth noting that the Bonneville to Rock Island IDL is used for the yearling Wells summer Chinook ERA, whereas the Bonneville to Wells IDL is used for the yearling Okanagan summer Chinook ERA. The CTC uses Wells Hatchery as it's indicator stock for the Upper Columbia summer Chinook aggregate and has an escapement goal at Rock Island Dam for this stock aggregate. Because the escapement goal occurs at Rock Island, all escapement CWT recoveries occurring upstream of Rock Island Dam (e.g. spawning ground recovery on the Wenatchee or brood stock collection at Wells Dam) are considered part of escapement (this was not the case for the yearling Okanagan ERA). For this reason, an IDL estimate from Bonneville to Rock Island needs to be used for yearling Wells summer Chinook. However, for yearling Okanagan summer Chinook escapement was defined as any location upstream, but not including, Wells Dam. For this reason, an IDL estimate for Bonneville to Wells Dam needs to be used for yearling Okanagan summer Chinook. Ideally, both stocks would use the same IDL estimate for comparative purposes, but this would require generating new lookup tables that the CTC produces to remap recoveries for yearling Wells summer Chinook.

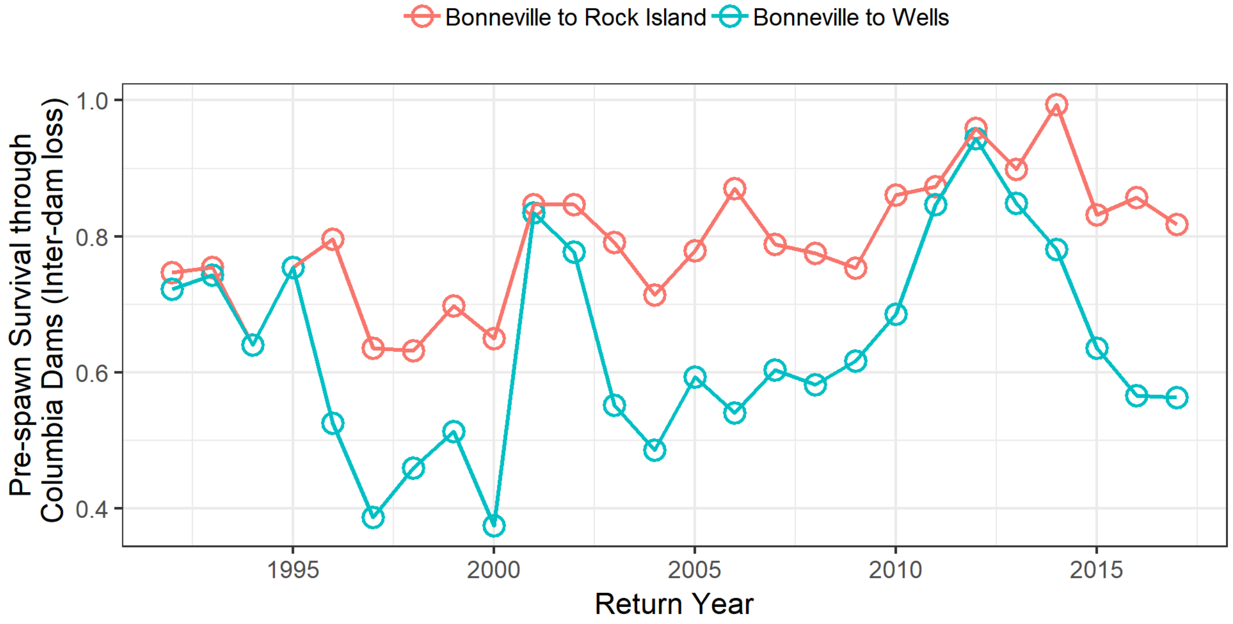

Figure 2. Inter-dam loss (IDL) estimates from Bonneville to Rock Island Dam (used for yearling Wells summer Chinook) and Bonneville to Wells Dam (used for yearling Okanagan summer Chinook).

Table 2. Inter-dam loss estimates by Columbia River Reach. Dam acronyms are Bonneville (BON), McNary (MCN), Priest Rapids (PRD), Rock Island (RI), Rocky Reach (RRE) and Wells (WE).

Run Year	BON - MCN	MCN - PRD	PRD - RI	RI - RRE	RRE - WE
1992	0.83	1.00	0.90	1.00	0.96
1993	0.96	1.00	0.79	1.00	0.98
1994	0.78	1.00	0.83	1.00	1.00
1995	0.86	1.00	0.87	1.00	1.00
1996	0.93	1.00	0.86	1.00	0.66
1997	0.83	1.00	0.75	1.00	0.62
1998	0.75	1.00	0.84	1.00	0.73
1999	0.78	1.00	0.99	0.75	0.88
2000	0.72	1.00	1.00	0.99	0.53
2001	0.92	1.00	1.00	1.00	0.91
2002	0.94	1.00	0.95	0.99	0.88
2003	0.81	1.00	1.00	0.90	0.76

Run Year	BON - MCN	MCN - PRD	PRD - RI	RI - RRE	RRE - WE
2004	0.77	1.00	1.00	0.80	0.79
2005	0.88	1.00	0.92	0.93	0.79
2006	0.87	1.00	1.00	0.92	0.67
2007	1.00	1.00	1.00	0.90	0.67
2008	0.80	1.00	1.00	0.90	0.81
2009	0.84	1.00	0.94	0.97	0.80
2010	0.90	1.00	1.00	0.85	0.90
2011	1.00	1.00	0.98	1.00	0.86
2012	0.96	1.00	1.00	1.00	0.98
2013	0.94	1.00	1.00	0.99	0.91
2014	1.00	1.00	1.00	0.87	0.90
2015	0.83	1.00	1.00	0.90	0.84
2016	0.87	1.00	1.00	0.81	0.81
2017	0.82	1.00	1.00	0.89	0.78

Exploitation Rate Analysis (ERA) Results

This section shows metrics from the ERA for yearling Okanagan and yearling Wells summer Chinook. These quantities represent some of the metrics that the CTC produces as part of their annual ERA process. For each metric, a one-to-one plot that helps to determine whether the mean and pattern of the metric is the same for yearling Okanagan and Wells summer Chinook is provided. Statistical tests of this one-to-one relationship are also provided by fitting a regression and examining the estimate of the slope and intercept. A statistical test of whether the intercept equals 0 is provided. A p-value of this test greater than a 0.05 significance level indicates that there is not evidence to suggest that mean of the metrics are different. A statistical test of whether the slope equals 1 is also provided. A p-value of this test greater than a 0.05 significance level indicates that there is not evidence to suggest that the pattern of the metrics are different. These results should be interpreted cautiously as they can be very sensitive and asking whether differences in metrics are biologically meaningful should also be given consideration.

Release to Age 3 Survival

Release to age 3 (prior to the CTC assumed natural mortality rate and fishing mortality) survival estimates are similar for yearling Okanagan and Wells summer Chinook (Figure 3). Both stocks exhibited lower than average survival prior to migration year 1997. Survival in migration years 1999 and 2013 was higher than average for both stocks. Figure 4 shows the one-to-one relationship between these two survival estimates. The statistical tests of this one-to-one relationship indicate that there is no evidence to suggest that the mean of these survivals rates are different, however there is slight evidence to suggest that the patterns of these survival rates are different.

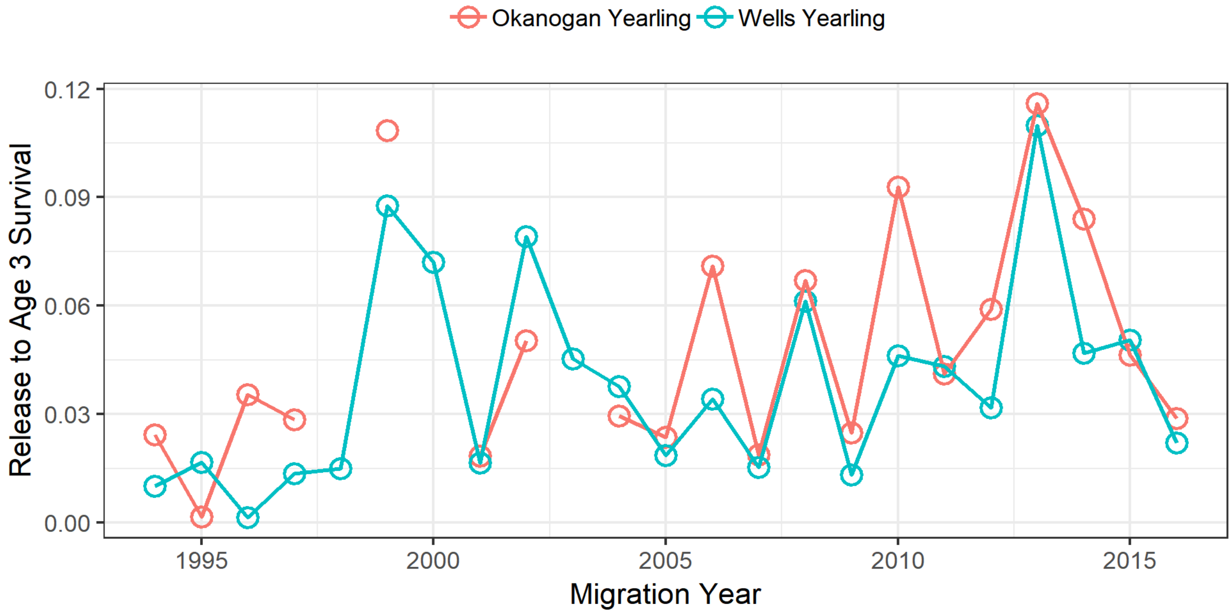

Figure 3. Release to age 3 survival by migration year for yearling Okanagan and Wells summer Chinook.

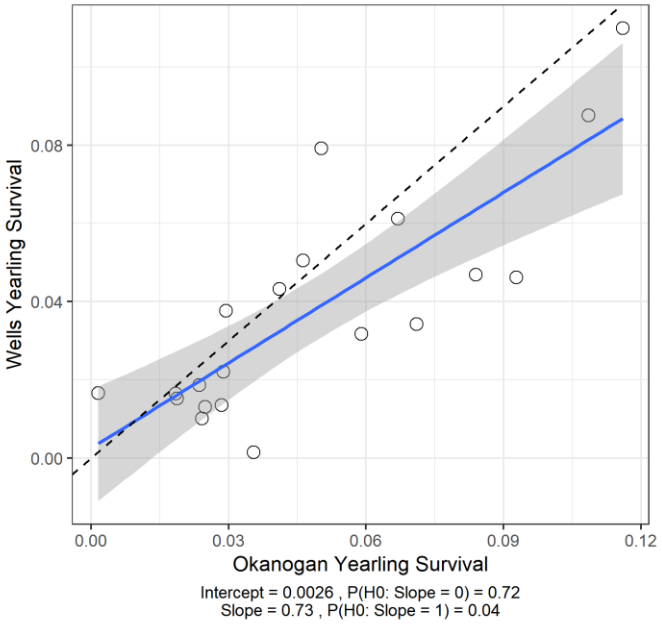

Figure 4: One-to-one plot comparing yearling Okanagan to Wells summer Chinook survival. The caption in the figure shows the intercept and slope of the linear regression fit along with the p-value of the null hypothesis that the intercept equals 0 and that the slope equals 1.

Maturation Rates

Maturation rates by brood year are shown in Figures 5 and 6. A visual inspection of Figure 5 indicates small differences in maturation by age between yearling Okanagan and Wells summer Chinook. These differences are more apparent in Figure 6 which indicates that yearling Okanagan summer Chinook have lower age 4 and age 5 maturation rates than yearling Wells summer Chinook. The opposite is true for Age 3 maturation rates. Figure 6 also shows an increasing trend in maturation rates for each age. This pattern has also been observed for many of the Chinook indicator stocks along the Pacific Coast that the CTC monitors.

The one-to-one relationships and statistical tests associated with them (Figure 7) support the patterns observed in Figures 5 and 6. The statistical tests for every age indicate that the mean maturation rates for yearling Okanagan and Wells summer Chinook are not equal as indicated by the p-values of the test that the intercept of the one-to-one plot equals 0. The p-values of the tests that the slope of the one-to-one plots equals 1 indicate that the pattern in age 3 and 5 maturation rates are not equal, but that the pattern in age 4 maturation rates are the same.

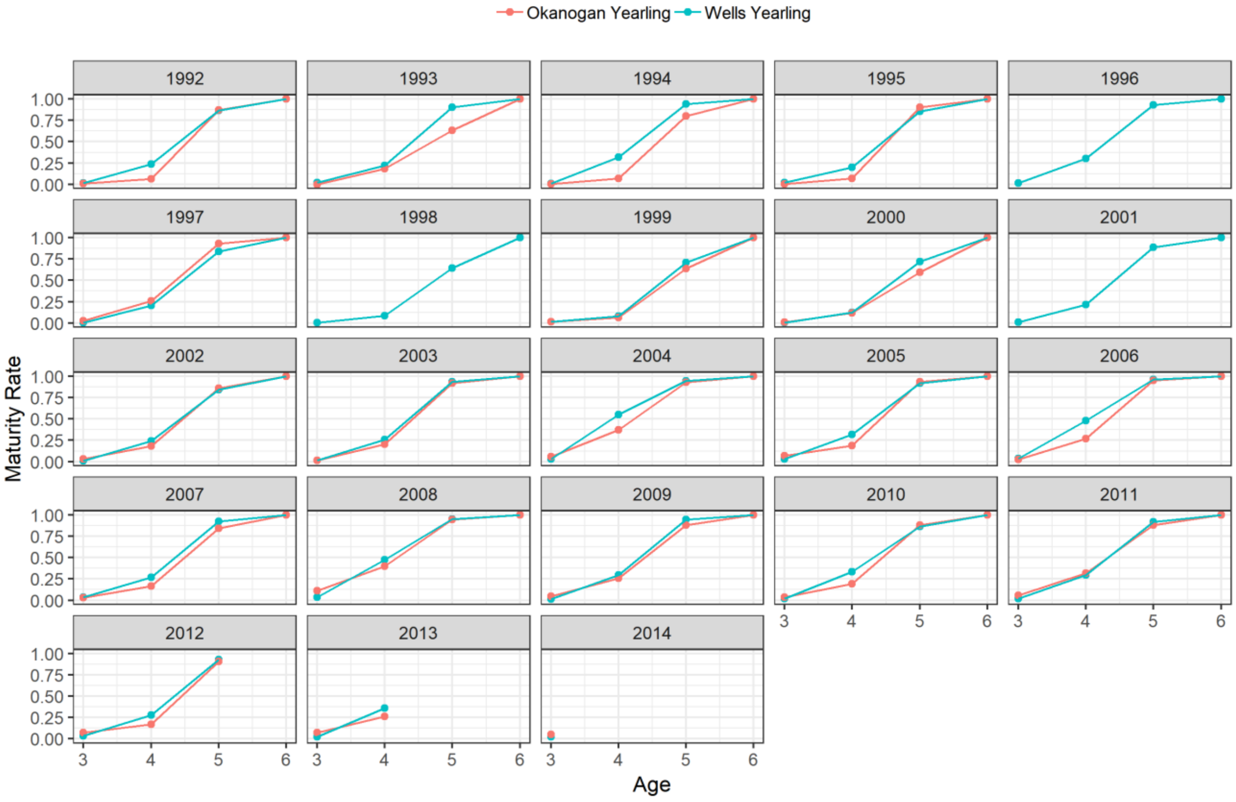

Figure 5. Maturation rates by stock, age and brood year (panels).

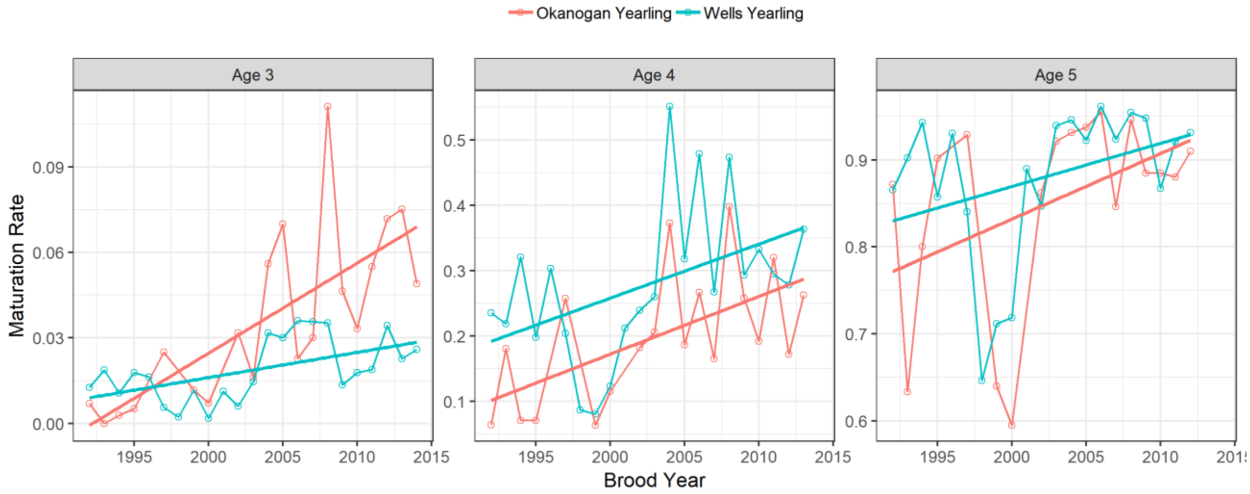

Figure 6. Maturation rates by brood year, stock and age (panels). A linear regression fit is shown for each stock and age combination.

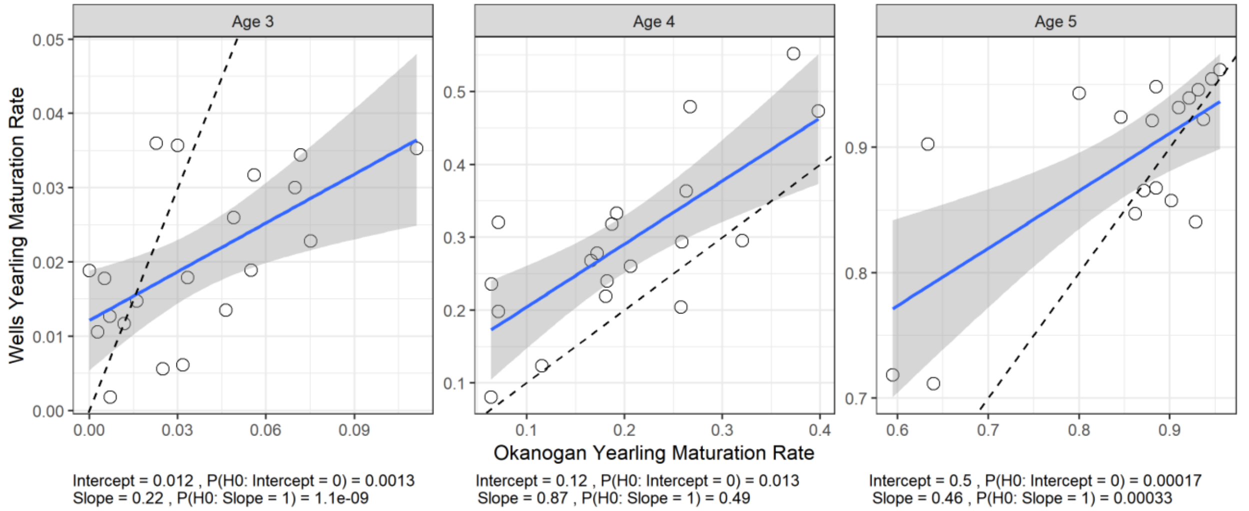

Figure 7. One-to-one plots comparing yearling Okanagan to Wells summer Chinook maturation rates by age (panels). The caption in each panel shows the intercept and slope of the linear regression fit along with the p-value of the null hypothesis that the intercept equals 0 and that the slope equals 1.

Mortality Distribution

Mortality distribution tables for yearling Okanagan and Wells summer Chinook are shown in Tables 4 and 5 respectively. These tables show the percentage of adult equivalent (AEQ) total mortality in a specific fisheries and escapement by calendar year. A condensed version of this distribution table is shown in Figures 8 and 9. These tables and figure indicate a northerly ocean distribution for both stocks as indicated by percentages of mortality in both SEAK and NBC AABM fisheries. Percentages of mortality in SEAK appear relatively similar between stocks with some discrepancies in the early 2000's. In more recent years, the percentage of mortality appear slightly different in the NBC AABM fishery. The opposite is true in the WCVI AABM fishery where percentages of mortality have been similar in more recent years, but were noticeably different prior to 2010. There are noticeable differences between stocks in the mean percentage of total mortality in US ISBM fisheries and Escapement / Stray. These differences should be interpreted cautiously as they are likely very sensitive to the IDL estimate. Any errors or nuances associated with the IDL estimate would have an amplified effect on the percentage of total mortality in US ISBM fisheries and Escapement/Stray relative to the Canadian ISBM and AABM fisheries.

The matrix in Table 3 provides an overview of the conclusions drawn from the statistical tests of the one-to-one percentage of mortality relationships. All statistical tests indicated that the pattern of percentage of mortality were the same. The mean percentages of mortality, however, differed in the WCVI AABM, Canadian ISBM and Southern US ISBM fisheries.

Table 3. Summary of statistical test inferences for comparison of the mean distribution and pattern of distribution between the Wells and Okanagan CWT exploitation rates stocks among major PSC fisheries and escapement.

	Mean Distribution	Pattern of Distribution
SEAK AABM	Same	Same
NBC AABM	Same	Same
WCVI AABM	Different	Same
Canadian ISBM	Different	Same
Sothern US ISBM	Different	Same
Escapement / Stray	Same	Same

The mortality distributions presented in Tables 4 and 5 also provide the estimated number of CWT recoveries by calendar year, and Table 6 provides fishery mortalities and escapement by calendar year. The number of recoveries for yearling Okanagan summer Chinook are very robust and are only less than 1,000 in 1992. The number of recoveries for yearling Wells summer Chinook are also robust, but not as large as those for the Okanagan stock. The number of estimates CWT recoveries for yearling Wells summer Chinook prior to 1996 is always less than 1,000 and is very small in 1994 and 1995.

The percentage of mortality in the “Stray” category for yearling Okanagan summer Chinook is very high prior to 2000 ranging from 7 to 28% (Table 4). These high percentages can be explained by high percentage of CWT recoveries at Wells Dam or Hatchery in this location. Recoveries at this location were considered “strays” whereas any recovery occurring upstream of this location was considered escapement. It is unknown why there were disproportionately high CWT recoveries at this location prior to 2000. It’s possible that spawning ground sampling rates were not high enough during this period which skewed proportion of recoveries occurring at this location.

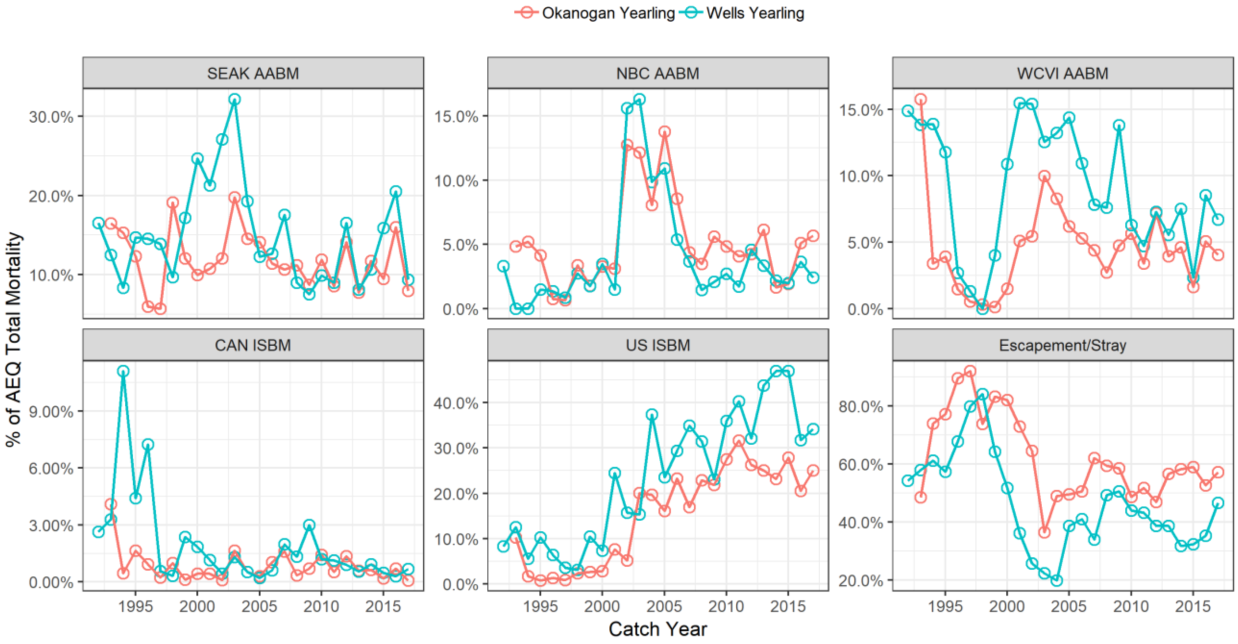

Figure 8. Condensed plot of the mortality distribution in Table 3 and 4.

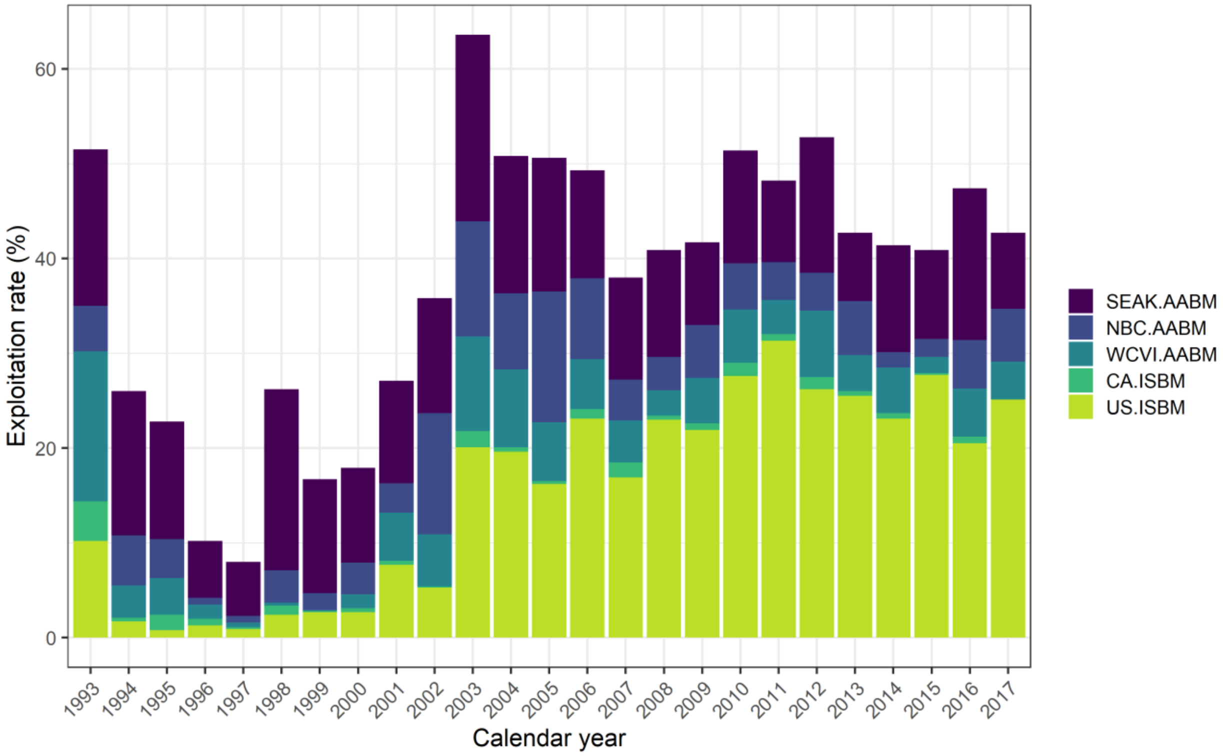

Figure 9. Condensed plot of the mortality distribution in Table 3 and 4.

Table 4. Yearling Okanagan summer Chinook mortality distribution expressed as the percent of adult equivalent (AEQ) total mortality. Fishery categories include Troll (T), Net (N) and Sport (S).

	Est		AABM Fishery							ISBM Fishery														Escapement	
Catch	# of		SEAK			NBC		WCVI		NBC & CBC			Southern BC			N Falcon		S Falcon		Puget Sd		Columbia			
Year	CWT	Ages	T	N	S	T	S	T	S	T	N	S	T	N	S	T	S	T	S	N	S	N	S	Stray	Esc.
1992	266	3	Failed Criteria			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1993	1218	3,4	14.2	0.4	1.9	4.5	0.3	14.9	0.9	1.0	2.1	0.0	0.0	0.4	0.7	2.1	2.6	0.2	0.0	0.0	0.9	3.9	0.5	13.5	35.0
1994	3667	3,4,5	10.4	3.8	1.0	4.6	0.7	3.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	1.4	0.1	19.6	54.3
1995	2381	3,4,5,6	9.2	0.3	2.9	1.7	2.4	3.5	0.4	0.3	0.9	0.0	0.0	0.3	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.3	0.3	19.9	57.2
1996	1837	3,4,5,6	5.2	0.1	0.7	0.5	0.2	1.3	0.2	0.0	0.2	0.2	0.0	0.0	0.3	0.4	0.0	0.3	0.2	0.0	0.0	0.0	0.4	27.9	61.6
1997	3783	3,4,5,6	4.5	0.0	1.2	0.1	0.6	0.5	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.6	0.0	0.0	0.0	0.1	0.0	16.7	75.4
1998	1009	3,4,5,6	18.6	0.5	0.0	3.4	0.0	0.0	0.3	0.0	0.0	0.9	0.0	0.1	0.0	0.0	0.2	0.6	0.0	0.0	0.0	1.3	0.3	23.6	50.2
1999	2557	4,5,6	9.6	0.0	2.4	0.4	1.4	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.9	0.2	1.1	0.0	0.0	0.0	0.2	0.3	9.7	73.5
2000	6306	3,5,6	8.7	0.3	1.0	2.0	1.3	1.3	0.2	0.0	0.3	0.1	0.0	0.0	0.0	0.4	0.3	0.6	0.0	0.0	0.0	0.1	1.3	7.4	74.6
2001	8381	4,6	9.3	0.3	1.2	1.7	1.4	4.3	0.8	0.0	0.0	0.3	0.0	0.0	0.1	2.0	0.9	3.8	0.5	0.0	0.0	0.2	0.3	2.5	70.5
2002	12555	3,5	11.4	0.0	0.7	11.0	1.8	5.3	0.2	0.0	0.0	0.1	0.0	0.0	0.0	1.2	0.8	0.6	0.1	0.0	0.0	0.6	2.0	0.8	63.7
2003	1522	3,4,6	16.4	0.1	3.2	8.7	3.4	9.5	0.5	0.0	0.0	1.6	0.0	0.0	0.1	3.7	1.9	3.2	0.6	0.1	0.5	2.7	7.4	2.4	34.0
2004	4151	4,5	12.3	0.8	1.4	5.7	2.3	7.5	0.7	0.0	0.0	0.4	0.0	0.0	0.1	2.8	0.7	2.9	0.6	0.0	0.2	6.8	5.6	0.6	48.4
2005	5890	3,5,6	12.9	0.1	1.1	9.2	4.6	6.0	0.2	0.0	0.1	0.0	0.0	0.0	0.2	1.4	0.6	2.2	0.2	0.0	0.0	7.6	4.2	2.3	47.2
2006	2678	3,4,6	8.4	2.1	0.9	5.2	3.3	4.6	0.7	0.0	0.0	0.0	0.0	0.0	1.0	2.4	0.2	0.5	0.1	0.0	0.1	14.2	5.6	1.2	49.3
2007	4588	3,4,5	8.4	0.7	1.6	1.6	2.7	3.8	0.6	0.0	0.9	0.4	0.0	0.0	0.3	0.9	0.6	0.6	0.3	0.0	0.1	5.0	9.5	0.6	61.5
2008	10404	3,4,5,6	10.3	0.1	0.9	1.3	2.2	1.7	1.0	0.0	0.0	0.1	0.0	0.0	0.3	0.9	0.4	0.0	0.0	0.0	0.0	16.2	5.5	2.0	57.3
2009	8191	3,4,5,6	7.8	0.1	0.8	3.0	2.6	3.1	1.7	0.0	0.0	0.2	0.0	0.0	0.5	0.9	0.3	0.0	0.0	0.0	0.2	15.2	5.3	2.5	56.0
2010	7222	3,4,5,6	10.0	0.3	1.6	3.4	1.5	4.9	0.7	0.0	0.0	1.2	0.0	0.0	0.2	2.9	1.1	0.9	0.0	0.0	0.1	16.9	5.6	1.4	47.3
2011	11643	3,4,5,6	7.5	0.1	0.9	2.8	1.3	2.1	1.3	0.0	0.0	0.4	0.0	0.0	0.2	0.6	1.2	1.2	0.2	0.0	0.1	18.4	9.9	0.9	50.9
2012	9774	3,4,5,6	12.9	0.5	0.7	3.0	1.2	4.7	2.4	0.0	0.0	0.4	0.0	0.0	0.9	4.5	3.2	3.4	1.0	0.0	0.2	6.8	7.1	0.7	46.1
2013	7917	3,4,5,6	6.8	0.3	0.6	3.7	2.4	2.7	1.3	0.0	0.0	0.1	0.0	0.0	0.5	3.2	1.2	2.6	0.4	0.0	0.3	12.4	5.0	0.6	56.0
2014	10603	3,4,5,6	10.6	0.4	0.7	0.9	0.8	4.1	0.5	0.0	0.0	0.4	0.1	0.0	0.1	3.8	1.5	2.3	0.1	0.0	0.0	11.6	3.7	1.0	57.2
2015	18526	3,4,5,6	8.5	0.1	0.8	1.3	0.6	1.1	0.6	0.0	0.0	0.1	0.0	0.0	0.1	3.4	2.4	1.3	0.1	0.0	0.0	15.7	5.0	0.4	58.6
2016	16209	3,4,5,6	14.4	0.4	1.2	3.1	2.0	4.1	1.0	0.0	0.0	0.4	0.0	0.0	0.3	1.4	0.6	2.4	0.0	0.0	0.0	12.7	3.4	2.8	49.8
2017	7057	3,4,5,6	6.4	0.3	1.3	2.6	3.0	3.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.4	0.8	0.1	0.0	0.1	14.9	5.7	3.2	54.0

Table 5. Yearling Wells summer Chinook mortality distribution expressed as the percent of adult equivalent (AEQ) total mortality. Fishery categories include Troll (T), Net (N) and Sport (S).

	Est		AABM Fishery							ISBM Fishery														Escapement	
Catch	# of		SEAK			NBC		WCVI		NBC & CBC			Southern BC			N Falcon		S Falcon		Puget Sd		Columbia			
Year	CWT	Ages	T	N	S	T	S	T	S	T	N	S	T	N	S	T	S	T	S	N	S	N	S	Stray	Esc.
1992	302	4,5,6	16.6	0.0	0.0	3.3	0.0	14.9	0.0	2.0	0.0	0.0	0.0	0.0	0.7	3.0	0.0	2.3	0.0	0.0	1.3	0.7	1.0	0.7	53.6
1993	152	3,5,6	12.5	0.0	0.0	0.0	0.0	13.8	0.0	0.0	3.3	0.0	0.0	0.0	0.0	4.6	2.0	2.6	0.0	0.0	0.0	3.3	0.0	0.7	57.2
1994	36	4,6	8.3	0.0	0.0	0.0	0.0	2.8	11.1	0.0	0.0	11.1	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.1
1995	68	3,5	11.8	0.0	2.9	0.0	1.5	11.8	0.0	0.0	0.0	0.0	0.0	2.9	1.5	4.4	0.0	2.9	0.0	2.9	0.0	0.0	0.0	0.0	57.4
1996	372	3,4,6	12.6	0.3	1.6	1.1	0.3	2.7	0.0	0.0	3.0	0.0	0.0	0.3	2.2	0.5	0.0	3.0	0.8	0.0	0.0	0.0	2.2	0.0	67.7
1997	1071	3,4,5	9.8	0.0	4.1	0.3	0.6	1.3	0.0	0.0	0.4	0.0	0.0	0.0	0.2	0.0	0.0	2.7	0.0	0.0	0.2	0.1	0.6	0.0	79.8
1998	1521	3,4,5,6	8.5	0.2	0.9	0.1	2.6	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.1	0.0	1.8	0.0	0.0	0.0	0.9	0.2	0.1	84.1
1999	802	3,4,5,6	14.0	0.4	2.9	0.7	1.0	0.5	3.5	0.0	0.4	1.0	0.0	0.0	1.0	5.2	0.5	2.9	0.0	0.0	0.0	0.9	1.0	0.0	64.2
2000	2152	3,4,5,6	19.0	0.7	4.8	0.3	3.2	5.2	5.7	0.0	0.0	0.7	0.0	0.0	0.6	1.0	1.5	2.3	0.0	0.0	0.0	0.7	1.8	0.1	51.6
2001	6802	3,4,5,6	17.4	2.0	1.9	0.6	0.9	13.0	2.4	0.0	0.0	0.6	0.0	0.0	0.5	7.5	2.3	10.0	1.2	0.0	1.5	0.7	1.2	0.4	35.8
2002	9613	3,4,5,6	25.6	0.0	1.5	14.0	1.6	14.0	1.4	0.0	0.0	0.3	0.0	0.0	0.1	5.8	2.9	3.2	0.6	0.0	0.0	0.8	2.4	0.3	25.5
2003	6297	3,4,5,6	30.4	0.5	1.3	15.0	1.3	12.3	0.3	0.0	0.0	1.1	0.0	0.0	0.2	3.2	0.5	4.2	0.6	0.0	0.1	2.6	4.2	0.3	22.0
2004	4559	3,4,5,6	17.5	0.4	1.4	7.5	2.3	12.1	1.1	0.0	0.0	0.2	0.0	0.0	0.3	5.0	0.5	5.9	0.7	0.0	0.3	7.7	17.2	0.0	19.7
2005	6837	3,4,5,6	11.3	0.0	0.9	8.1	2.8	13.5	0.8	0.0	0.0	0.1	0.0	0.0	0.1	3.3	0.4	5.0	0.2	0.0	0.0	5.9	8.9	0.0	38.6
2006	4204	3,4,5,6	11.9	0.0	0.7	4.0	1.3	10.0	0.9	0.0	0.0	0.4	0.0	0.0	0.2	2.6	0.1	0.3	0.2	0.1	0.1	15.7	10.2	0.0	41.1
2007	3875	3,4,5,6	13.0	2.2	2.4	1.5	2.2	6.7	1.1	0.0	1.0	0.4	0.0	0.0	0.6	3.2	0.2	1.9	0.5	0.0	0.8	10.2	18.2	0.5	33.5
2008	3761	3,4,5,6	8.3	0.1	0.6	0.9	0.5	5.0	2.6	0.0	0.1	0.7	0.0	0.0	0.5	2.4	0.6	0.0	0.0	0.0	0.3	17.9	10.3	0.0	49.2
2009	2701	3,4,5,6	6.5	0.3	0.8	1.4	0.7	5.1	8.7	0.0	0.0	0.6	0.0	0.0	2.4	1.6	0.6	0.0	0.0	0.0	1.1	11.7	8.1	0.0	50.5
2010	5135	3,4,5,6	8.8	0.0	1.1	1.7	1.0	5.7	0.6	0.0	0.0	0.2	0.0	0.0	1.0	5.3	0.2	2.4	0.2	0.0	0.0	20.4	7.4	0.0	43.9
2011	3694	3,4,5,6	8.5	0.1	0.3	0.7	1.0	2.6	2.1	0.0	0.0	0.6	0.0	0.0	0.6	1.4	1.2	2.0	0.2	0.0	0.6	20.6	14.2	0.0	43.2
2012	4787	3,4,5,6	14.9	0.7	0.9	3.7	0.9	5.0	2.3	0.0	0.0	0.3	0.0	0.0	0.6	5.8	2.5	4.3	0.7	0.0	0.3	8.9	9.7	0.0	38.6
2013	4087	3,4,5,6	6.8	0.9	0.4	2.1	1.2	3.6	1.9	0.0	0.0	0.2	0.0	0.0	0.3	5.7	0.6	3.4	0.7	0.0	0.3	20.9	12.3	0.3	38.4
2014	5029	3,4,5,6	9.7	0.6	0.4	1.6	0.6	7.1	0.4	0.0	0.0	0.7	0.1	0.0	0.2	5.2	1.1	4.4	0.2	0.0	0.2	27.2	8.7	0.0	31.8
2015	6981	3,4,5,6	14.3	0.6	1.0	1.2	0.8	1.9	0.5	0.0	0.0	0.4	0.0	0.0	0.0	6.3	1.1	3.3	0.0	0.0	0.1	24.2	11.8	0.0	32.4
2016	8857	3,4,5,6	19.8	0.4	0.3	3.1	0.6	8.0	0.5	0.0	0.0	0.3	0.0	0.0	0.0	1.9	0.1	3.7	0.4	0.0	0.0	14.1	11.6	0.0	35.2
2017	6114	3,4,5,6	8.4	0.3	0.7	2.0	0.4	6.6	0.1	0.0	0.0	0.7	0.0	0.0	0.0	3.6	0.4	1.2	0.1	0.0	0.0	14.7	14.3	0.0	46.6

Table 6. Yearling Okanagan summer Chinook mortality distribution expressed as the adult equivalent (AEQ) fishery mortalities and escapement. Fishery categories include Troll (T), Net (N) and Sport (S).

	Est Ttl	AABM Fishery							ISBM Fishery														Escapement	
Catch	# of	SEAK			NBC		WCVI		NBC & CBC			Southern BC			N Falcon		S Falcon		Puget Sd		Columbia			
Year	Chinook	T	N	S	T	S	T	S	T	N	S	T	N	S	T	S	T	S	N	S	N	S	Stray	Esc.
1993	4,243	602	17	81	191	13	632	38	42	89	-	-	17	30	89	110	8	-	-	38	165	21	573	1,485
1994	7,427	772	282	74	342	52	238	15	15	15	-	-	-	-	7	-	-	7	-	-	104	7	1,456	4,033
1995	5,248	483	16	152	89	126	184	21	16	47	-	-	16	5	-	-	5	5	-	-	16	16	1,044	3,002
1996	2,953	154	3	21	15	6	38	6	-	6	6	-	-	9	12	-	9	6	-	-	-	12	824	1,819
1997	2,903	131	-	35	3	17	15	-	-	3	-	-	3	-	3	3	17	-	-	-	3	-	485	2,189
1998	2,175	405	11	-	74	-	-	7	-	-	20	-	2	-	-	4	13	-	-	-	28	7	513	1,092
1999	4,921	472	-	118	20	69	-	5	-	-	5	-	-	-	44	10	54	-	-	-	10	15	477	3,617
2000	4,961	432	15	50	99	64	64	10	-	15	5	-	-	-	20	15	30	-	-	-	5	64	367	3,701
2001	15,400	1,432	46	185	262	216	662	123	-	-	46	-	-	15	308	139	585	77	-	-	31	46	385	10,857
2002	21,754	2,480	-	152	2,393	392	1,153	44	-	-	22	-	-	-	261	174	131	22	-	-	131	435	174	13,857
2003	10,059	1,650	10	322	875	342	956	50	-	-	161	-	-	10	372	191	322	60	10	50	272	744	241	3,420
2004	13,886	1,708	111	194	792	319	1,041	97	-	-	56	-	-	14	389	97	403	83	-	28	944	778	83	6,721
2005	18,833	2,429	19	207	1,733	866	1,130	38	-	19	-	-	-	38	264	113	414	38	-	-	1,431	791	433	8,889
2006	17,446	1,465	366	157	907	576	803	122	-	-	-	-	-	174	419	35	87	17	-	17	2,477	977	209	8,601
2007	7,182	603	50	115	115	194	273	43	-	65	29	-	-	22	65	43	43	22	-	7	359	682	43	4,417
2008	12,173	1,254	12	110	158	268	207	122	-	-	12	-	-	37	110	49	-	-	-	-	1,972	670	243	6,975
2009	13,471	1,051	13	108	404	350	418	229	-	-	27	-	-	67	121	40	-	-	-	27	2,048	714	337	7,544
2010	12,584	1,258	38	201	428	189	617	88	-	-	151	-	-	25	365	138	113	-	-	13	2,127	705	176	5,952
2011	19,020	1,426	19	171	533	247	399	247	-	-	76	-	-	38	114	228	228	38	-	19	3,500	1,883	171	9,681
2012	17,842	2,302	89	125	535	214	839	428	-	-	71	-	-	161	803	571	607	178	-	36	1,213	1,267	125	8,225
2013	14,632	995	44	88	541	351	395	190	-	-	15	-	-	73	468	176	380	59	-	44	1,814	732	88	8,194
2014	21,266	2,254	85	149	191	170	872	106	-	-	85	21	-	21	808	319	489	21	-	-	2,467	787	213	12,164
2015	23,423	1,991	23	187	305	141	258	141	-	-	23	-	-	23	796	562	305	23	-	-	3,677	1,171	94	13,726
2016	21,295	3,067	85	256	660	426	873	213	-	-	85	-	-	64	298	128	511	-	-	-	2,704	724	596	10,605
2017	18,746	1,200	56	244	487	562	694	56	-	-	-	-	-	-	394	262	150	19	-	19	2,793	1,069	600	10,123

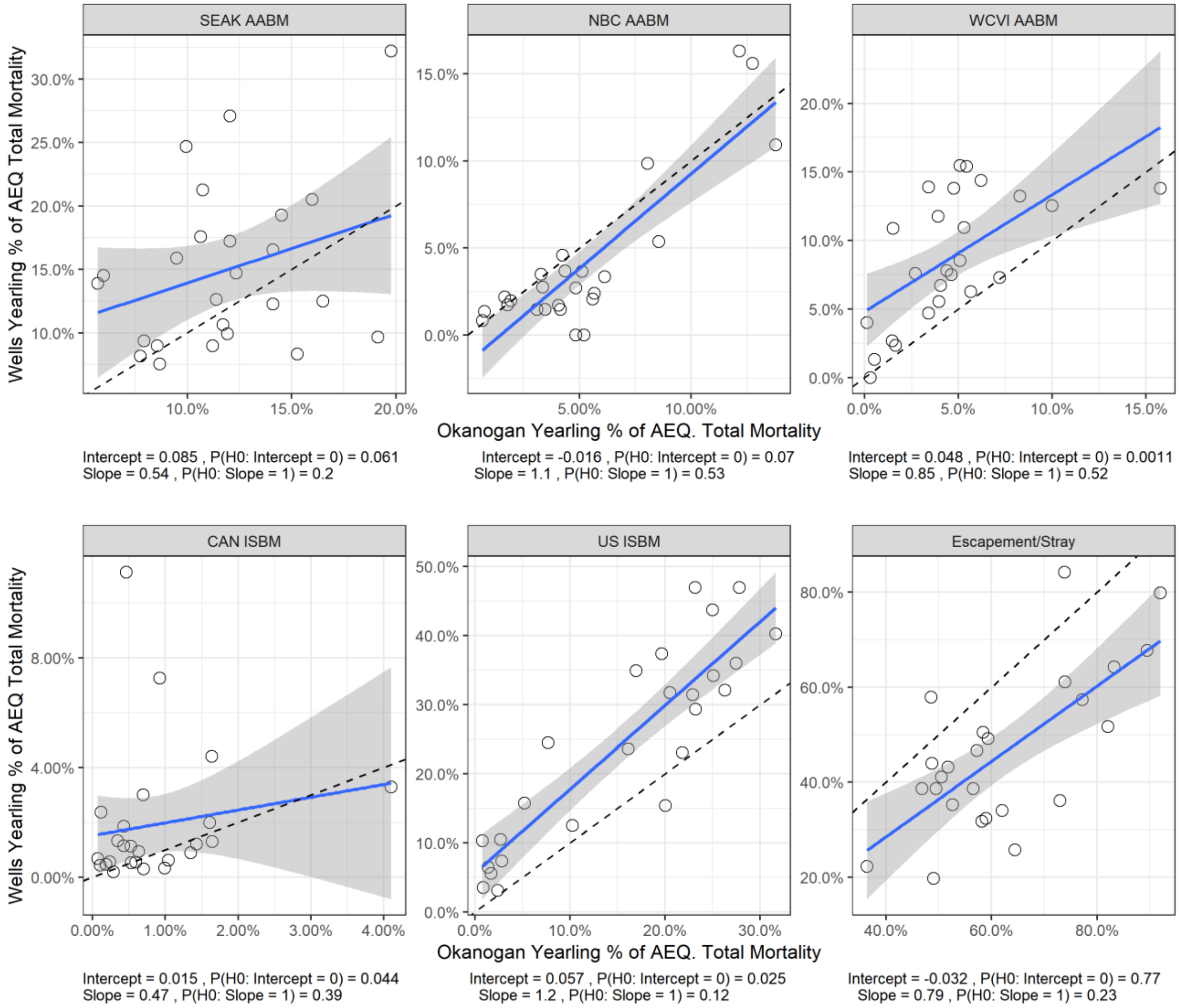

Figure 9. One-to-one plots comparing yearling Okanagan to Wells summer Chinook mortality distributions by fishery categories (panels). The caption in each panel shows the intercept and slope of the linear regression fit along with the p-value of the null hypothesis that the intercept equals 0 and that the slope equals 1.

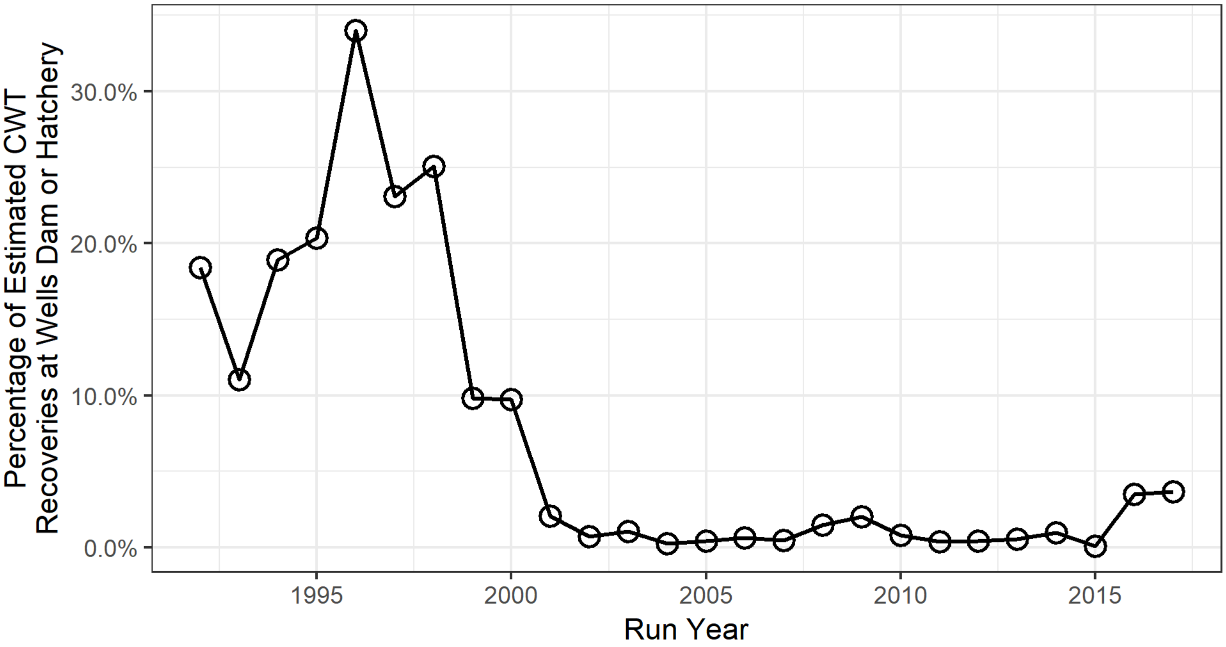

Figure 10. Percentage of estimated Coded Wire Tag recoveries (relative to all recoveries) by run year for yearling Okanagan summer Chinook.

References

CTC. 2018. Annual report of the exploitation rate analysis and model calibration. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINO

APPENDIX C: UPPER COLUMBIA PUD HYDROSYSTEM OPERATIONS

This document summarizes juvenile passage operations at the public utility district hydro electric projects on the mainstem Columbia River. The five dams are owned and operated by three public utility districts. From upstream to downstream: Douglas County (Wells project), Chelan County (Rocky Reach and Rock Island projects) and Grant County (Wanapum and Priest Rapids projects). Douglas and Chelan Counties manage their fish and wildlife programs in accordance with Habitat Conservation Plans (HCP). Grant County does not have an HCP for its projects, but a Biological Opinion. All five projects are licensed by the Federal Energy and Regulatory Commission.

Wells

- Normal operation of the Juvenile Bypass System (modified spillways with constricting barriers to improve the attraction flow while using modest levels of water) uses 10 kcfs.
- JBS will use approximately 6% to 8% of the total river flow for fish guidance
- Annual start and stop dates within that period are set by the HCP CC based on annually updated long-term monitoring, to bracket the run timing of at least 95% of both the spring and summer migrants
- "The Wells Project JBS is the most efficient bypass system on the mainstem Columbia River."

Rocky Reach

Spring Spill:

- None; Chelan operates its JFBS continuously through the spring and summer, beginning April 1

Summer Spill:

- Begins late May to early June, upon arrival of subyearling Chinook smolts, and ends no later than Aug 15th or at 95% of the summer outmigration
- spill 9% of day average river flow for a duration covering 95% of sub yearling outmigration past the dam

Rock Island

Spring Spill:

- Rock Island spill begins no later than 17 April (when the daily smolt passage index count exceeds 400 fish for more than 3 days) and will end spill after 95 percent of spring outmigrants have passed the dam (usually the first week of June), with spill being provided for at least 95% of the spring species outmigration.
- Spring Spill: <u>Average</u> 10% of day average flow for spring outmigration

Summer Spill:

- Rock Island summer spill in 2018 will begin immediately after completion of the spring spill. The summer spill level will be 20 percent of day average flow, shaped to increase spill efficiency. Spill will continue for a duration covering 95 percent of the subyearling

Chinook outmigration.

- Summer Spill: 20% of day average flow for subyearling (summer) Chinook

Wanapum

GPUD has an operation called "Fish Mode", which refers to special turbine and bypass operations during the juvenile outmigration window at Wanapum and Priest Rapids. During Fish Mode:

- Turbine units are operated between 11.8 to 15.7 kcfs
- Turbines are "ganged" when in operation
- Turbines furthest from the spillway are last to be turned on and first to be turned off
- Wanapum Fish Bypass will be operated at 20 kcfs during the entire juvenile salmonid outmigration
- However, WFB would be operated at 15 kcfs if tailwater conditions were less than 488.0 ft. in elevation or tailwater discharge was less than 60 kcfs
- Sluiceways are opened for adult fallback after the juvenile passage season and until Nov 15

Priest Rapids

During Fish Mode:

- Turbine units are operated between 9.0 to 17.4 kcfs.
- Turbines are "ganged" when in operation
- Turbines furthest from the spillway are last to be turned on and first to be turned off
- The PRFB was designed to operate at a fix flow volume of 26 kcfs
- Sluiceways are opened for adult fallback after the juvenile passage season and until Nov 15

Sources

2019 Total Dissolved Gas Abatement Plan Wells Hydroelectric Project, Ferc Project No. 2149

https://douglaspud.org/HCP%20Documents/2018%20Wells%20HCP%20Annual%20Report%20with%20trans%20letter.pdf

https://www.chelanpud.org/docs/default-source/default-document-library/2018-rocky-reach-hcp-annual-report__full.pdf. Appendix J. Beginning on pdf page 1133.

https://www.grantpud.org/templates/galaxy/images/images/Downloads/ResourceCommittees/OtherDocuments/2017_04_14_2016_Activities_Under_PRP.pdf. Sections 2.3, 3.0 and 4.0

APPENDIX D: DETAILED DESCRIPTION OF PIT TAG INTERROGATION SITES

Table 1. Description of PIT Tag Interrogation Sites in the Okanagan River Basin. Sites are ordered in descending order by latitude. Descriptions of each site were taken from www.ptagis.org/sites/interrogation-site-metadata and shortened for brevity.

Site Name	First Year	Location	Description
Penticton Channel Array (OKP)	2017	Mainstem	Penticton Channel is the channelized portion of the Okanagan River connecting Okanagan Lake with Skaha Lake within the city of Penticton BC.
Shuttleworth Creek (OKW)	2016	Tributary	Two antennas are installed in Shuttleworth Creek, a tributary to the Okanagan River in Canada, immediately upstream of the bridge at Cedary Street.
McIntyre Dam (OKM)	2019	Mainstem	McIntyre Dam is located upstream of Vaseux Lake and downstream of Okanagan Lake. Two antennas are mounted perpendicular to the water along the pier noses on each side of spill bay 1 at McIntyre Dam to detect upstream migrating sockeye which commonly leap over the overshot gates at the edges of the spill bay where the antennas are mounted.
Okanagan Channel at VDS-3 (OKC)	2009	Mainstem	The OKC site is located in the Okanagan Channel at 310th Avenue/Road 18 upstream from Osoyoos Lake. The river in this section is channelized and Vertical Drop Structures (VDS) are used to control the river gradient. The array is located approximately 130 ft downstream of VDS-3. The river at this location is approximately 80 ft wide, enabling nearly full coverage of the width with four 20-ft antennas. Four new antennas were added to the site in a second array in March 2017.
Inkaneep Creek (OKI)	2015	Tributary	Three pipe antennas are installed in Inkaneep Creek, a tributary to the Okanagan River in Canada, immediately upstream of the bridge at Radio Tower Road.
Ninemile Creek Instream Array (NMC)	2011	Tributary	Ninemile Creek enters east side of Lake Osoyoos at Okanagan River RKM 129.5, north of the town of Oroville, WA. Site NMC is located on Ninemile Creek, 0.78 km upstream from the confluence with Lake Osoyoos. The setup consists of 4 pass-through PVC antennas in series.
Tonasket Creek (TON)	2014	Tributary	Tonasket Creek enters the Okanagan River in Lake Osoyoos at RKM 129.4, in the town of Oroville, WA. TON is located approximately 0.4 RKM upstream from the confluence of Lake

(ZSL)

Site Name	First Year	Location	Description
			Osoyoos. The site consists of a single antenna anchored upright for pass-through detection.
Zosel Dam Combined (ZSL)	2010	Mainstem	Zosel Dam is located at Okanagan River km 132, approximately 3 km downstream from the outlet of Lake Osoyoos in the town of Oroville, Washington. The dam has two fish ladders and four spillbays. PIT tag detection was established at the dam by attaching antennas to the downstream faces of two weirs in each fish ladder.
Wildhorse Spring Creek (WHS)	2014	Tributary	Wildhorse Spring Creek enters the Okanagan River at RKM 113.1, approximately 9.8 RKM upstream from the town of Ellisforde, WA. WHS is located approximately 0.2 RKM upstream from the confluence of the Okanagan River. The site consists of a single antenna anchored upright for pass-through detection.
Antoine Creek Instream Array (ANT)	2011	Tributary	Antoine Creek enters the Okanagan River at RKM 98.5, approximately 6 km upstream from the city of Tonasket, WA. Site ANT is located on Antoine Creek, 0.48 km upstream from the confluence with the Okanagan River. The site consists of 4 passthrough antennas in series.
Bonaparte Creek Instream Array (BPC)	2013	Tributary	BPC is a permanent PIT Tag Interrogation System on Bonaparte Creek. Bonaparte Creek enters the Okanagan River at RKM 91.2, within the city of Tonasket, WA. The BPC site is located 0.08 km from the confluence with the Okanagan River. The setup consists of 3 flat plate pass-over antennas.
Aeneas Creek Temporary Array (AEN)	2014	Tributary	AEN is a permanent PIT tag interrogation site on Aeneas Creek. Aeneas Creek enters the Okanagan River at RKM 85.3, approximately 6.7 km down river from the town of Tonasket, WA. The AEN site is located approximately 0.2 km upstream from the confluence of the Okanagan River. The site consists of a single antenna anchored upright for pass-through detection.
Tunk Creek Instream Array (TNK)	2014	Tributary	Tunk Creek enters the Okanagan River at RKM 72.4. TNK is located approximately 0.2 RKM upstream from the confluence of the Okanagan River. The site consists of a single antenna anchored upright for pass-through detection.
Johnson Creek (JOH)	2014	Tributary	JOH is a permanent PIT tag interrogation site on Johnson Creek. Johnson Creek enters the Okanagan River at RKM 65.3, in the town of Riverside, WA. The JOH site is located approximately 0.2 km upstream from the confluence of the

Site Name	First Year	Location	Description
			Okanagan River. The site consists of a single antenna anchored upright for pass-through detection.
Riverside Acclimation Pond (RVP)	2015	Release Site	Riverside Acclimation Pond, located on the Okanagan River at 819 Omak Riverside Eastside Rd, Omak, WA. Site configuration was updated in 2018 to include three antennas located fitted within the release pipe in the vault at the end of the pond.
Wanacut Creek (WAN)	2014	Tributary	Wanacut Creek enters the Okanagan River at RKM 56.3, approximately 6.5 RKM upstream from the town of Omak, WA. WAN is located approximately 0.7 RKM upstream from the confluence of the Okanagan River. The site consists of a single antenna anchored upright for pass-through detection.
Omak Creek Instream Array (OMK)	2006	Tributary	OMK is a permanent PIT tag interrogation system in Omak Creek. Omak Creek enters the Okanagan River at RKM 51.5, approximately 1 km upstream from the city of Omak, WA. OMK is located 0.24 km from the confluence with the Okanagan River. In January 2018, the instream array was reconfigured with four antennas anchored to the stream bed for pass-over detection.
Omak Creek below Mission Falls (OBF)	2016	Tributary	Omak Creek enters the Okanagan River at RKM 51.5, approximately 1 KM upriver from the town of Omak, WA. The OBF site is located approximately 9.90 KM upstream from the confluence of the Okanagan River. The setup consists of one flat-plate antenna.
Omak Creek above Mission Falls (OMF)	2015	Tributary	OMF is a permanent PIT tag interrogation system located above Mission Falls in Omak Creek. Omak Creek enters the Okanagan River at RKM 51.5, approximately 1 KM upriver from the town of Omak, WA. The OMF site is located approximately 10.5 RKM upstream from the confluence of the Okanagan River. In March, 2018 the instream array was reconfigured with two antennas anchored to the stream bed for pass-over detection.
Salmon Creek Instream Array (SA1)	2011	Tributary	Salmon Creek enters the Okanagan River at RKM 41.3, in the city of Okanagan, WA. The site was originally located 2.9 km upstream from the confluence with the Okanagan River. In January 2018, the site was moved approximately 1 km downstream and reinstalled with 4 new antennas.

Site Name	First Year	Location	Description
Salmon Creek below OID Div (SA0)	2016	Tributary	Salmon Creek enters the Okanagan River at RKM 41.3, in the town of Okanagan, WA. The SA0 site is located approximately 6.35 KM upstream from the confluence of the Okanagan River. The setup consists of a two rows of flat plate antennas.
Loup Loup Creek Instream Array (LLC)	2013	Tributary	LLC is a permanent PIT Tag interrogation system on Loup Loup Creek. Loup Loup Creek enters the Okanagan River at RKM 27.2, within the city of Malott, WA. LLC is located 0.42 km from the confluence with the Okanagan River. In January 2018, the instream array was reconfigured with three antennas anchored to the stream bed for pass-over detection.
Lower Okanagan Instream Array (OKL)	2013	Mainstem	OKL is a permanent instream PIT tag interrogation site at RKM 24.9 on the mainstem Okanagan River, upstream of Chiliwist area in Okanagan County. The site consists of two rows of antennas, with each row spanning the wetted width of the channel during base flows.
Similkameen Acclimation Pond (SIP)	1996	Release Site	-

APPENDIX E: TERMS OF REFERENCE

PSC(ES) 19-2 Attachment Three

Terms of Reference for Okanagan Chinook Working Group

As recommended by CIG to the Commission

Background. During recent negotiations within the Pacific Salmon Commission to amend the current Chinook regime under Chapter 3, Annex IV of the Pacific Salmon Treaty, the Parties added a sub-paragraph regarding Okanagan Chinook salmon:

“5 (b) the Commission shall establish a work group to explore issues related to Okanagan Chinook, including the establishment of management objectives, enhancement and possible use of Okanagan Chinook as an indicator stock. The work group shall report to the Commission by October 2019;”

A footnote to paragraph 5(b) states that “The work shall be consistent with Paragraph 7 of Chapter 1 of this Treaty.” That paragraph states:

…the Parties shall consult with a view to developing, for the transboundary sections of the Columbia River, a more practicable arrangement for consultation and setting escapement targets than those specified in Article VII, paragraph 2 and 3. And any such arrangement is intended to *inter alia*:

- (a) Ensure effective conservation of the stocks;
- (b) Facilitate future enhancement of these stocks as jointly approved by the Parties;
- (c) Avoid interface with the United States management programs on the salmon stocks existing in the non-transboundary tributaries and the main stem of the Columbia River.

The Commission agreed at the January 2019 meeting to the following action”

> “A small workgroup on Okanagan Chinook is authorized. This group will include on Commissioner and two experts form each Party, and will develop its draft terms of reference consistent with the scope of Chapter 3, paragraph 5(b).”

Task list:

The workgroup shall develop concise summaries of the following items as a basis for the October report:

1) Summarize existing information on the population structure of Chinook spawning in the Okanagan River.
2) Summarize existing information on factors limiting the abundance, productivity, and spatial distribution of Chinook spawning in the U.S. and Canadian sections of the Okanagan River.
3) Describe existing actions to improve the abundance, productivity, and spatial distribution of Chinook spawning in the U.S. and Canadian sections of the Okanagan River.
4) Provide existing fishery management objectives for Chinook spawning in the Okanagan River.
5) Compile existing information on opportunities to enhance the productivity and abundance of Chinook salmon spawning in the U.S. and Canadian sections of the Okanagan River (habitat restoration; supplementation; water management).

6) Describe the current summer Chinook CWT indicator stock and identify whether any limitations exist in using it to monitor fishery impacts on Chinook salmon spawning in the Okanagan River.
7) Discuss new information that could assist the Parties in more effectively implementing Chapter 1, Paragraph 7, which may include a discussion of options for additional management objectives or fishery obligations in U.S. and Canadian fisheries and whether adoption of those measures could benefit the abundance, productivity, and spatial structure of Chinook salmon spawning in the Okanagan River.
8) Identify research projects that could promote the mutual, effective conservation of Chinook salmon spawning in the U.S. and Canadian sections of the Okanagan River.
9) Recommend annual reporting needs to inform the Commission over time.

Workgroup Members:

Canada: Dr. Brian Riddell {Commissioner), Mr. Chuck Parken {DFO), Mr. Howie Wright {ONA)

US: Mr. McCoy Oatman {Commissioner), Mr. Mike Matylewich (CRITFC), Mr. Bill Tweit {WDFW).

Time line:

By May 15, 2019. Discuss progress on tasks in conference call with CIG; resolve any questions that have arisen regarding the Terms of Reference.

By August 1, 2019. Discuss progress on tasks in conference call with CIG; resolve any questions that have arisen regarding the Terms of Reference.

By Sept 1, 2019. Provide CIG with draft report addressing paragraph S(b).