Okanagan Chinook: Summary of Findings and Considerations for Future Actions

Okanagan Work Group

October 2023

Pacific Salmon Commission
Technical Report No. 51

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For

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LIST OF ACRONYMS WITH DEFINITIONS

AABM Aggregate abundance-based Management
ADF&G Alaska Department of Fish and Game
AEQ Adult equivalent
AIS Aquatic Invasive Species
AK Alaska
AUC Area-Under-the-Curve
BC British Columbia
BY Brood year
C2 Coded Wire Tagging and Recovery/ Catch and Escapement Indicator Improvement Committee
CCT Colville Confederated Tribes
CEII Catch and Escapement Indicator Improvement
CFIA Canadian Food Inspection Agency
CIG Chinook Interface Group
CJH Chief Joseph Hatchery
CJS Cormack-Jolly-Seber
CMIP5 Coupled Model Intercomparison Project Phase 5
COSEWIC Committee on the Status of Endangered Wildlife in Canada
CPUE Catch per unit effort
CRITFC Columbia River Inter-Tribal Fish Commission
CRT Columbia River Treaty
CSS Comparative Survival Study
CTC Chinook Technical Committee
CV Coefficient of variation
CWT Coded-wire tag
CYER Calendar year exploitation rate
DART Data access in real time (Website)
DBE Difference between estimates
DFO Department of Fisheries and Oceans Canada
eDNA Environmental DNA
EDT Ecosystem Diagnosis and Treatment
EPA Environmental Protection Agency
ERA Exploitation rate analysis
ESA Endangered Species Act
FLNRORD Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FRAM Fishery Regulation Assessment Model
FWMT Fish and water management tool
GCM Global Climate Model
GIS Geographic information system
GSI Genetic stock identification
HOR Hatchery Origin Recruits
HOS Hatchery Origin Spawner
HSRG Hatchery Scientific Review Group
IDL Inter-dam loss
IHN Infectious hematopoietic necrosis
IM Incidental mortality
ISBM Individual stock-based management
ITC Introductions and Transfers Committee
LC Landed catch
MACA Multivariate Adaptive Constructed Analogs
MSF Mark-selective fishery
MSY Maximum Sustain Yield
NBC Northern British Columbia
NHC Northwest Hydraulic Consultants Ltd.
NOAA National Oceanic and Atmospheric Administration
NOR Natural Origin Recruits
NOS Natural Origin Spawners
NPDES National Pollutant Discharge Elimination System
OBMEP Okanagan Basin Monitoring and Evaluation Program
OBWB Okanagan Basin Water Board
ODFW Oregon Department of Fish and Wildlife
ONA Okanagan Nation Alliance
ORRI Okanagan River Restoration Initiative
OWG Okanagan Work Group
PBT Parentage-based tagging
PFMC Pacific Fishery Management Council
pHOS Proportion of Hatchery Origin Spawners
PIT Passive Integrated Transponder
PNI Proportionate natural influence
pNOB Proportion of Broodstock of Natural Origin
POT Peak over threshold
PSC Pacific Salmon Commission
PST Pacific Salmon Treaty
PUD Public Utility District

PVA	Population viability analysis
RAMs	Risk Assessment Methodology
RCP	Representative Concentration Pathway
rkm	River kilometers
RMIS	Regional Mark Information System
RRS	Relative reproductive success
RST	Rotary screw trap
SARA	Species at Risk Act
SARs	Smolt-to-adult return rates
SEAK	Southeast Alaksa
SEF	Southern Endowment Fund
SMK	Similkameen Summer Yearling
S_{MSY}	Escapement producing maximum sustainable yield
SNPs	Single nucleotide polymorphisms
SOWMA	South Okanagan Wildlife Management Area
TBD	To be determined
ToR	Terms of Reference
U.S.	United States
VDS	Vertical drop structure
VHS	Viral hemorrhagic septicemia
WA	Washington
WDFW	Washington Department of Fish and Wildlife
WSP	Wild Salmon Policy

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EXECUTIVE SUMMARY

The Okanagan Work Group (OWG) was established in January 2019 by the Pacific Salmon Commission (PSC) as an ad hoc effort to *"explore issues related to Okanagan Chinook salmon, including the establishment of management objectives, enhancement and possible use of Okanagan Chinook as an indicator stock"* per the 2019 Pacific Salmon Treaty (PST) Agreement, Chapter 3, paragraph 5(b) (PST 2020). Recognizing that "*successful Chinook conservation, restoration, and harvest management depends on a sustained and bilaterally coordinated program of resource protection, restoration, enhancement, and utilization*," the Commission empaneled a working group of scientists and Commissioners to accomplish the following tasks:

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 coded-wire tag (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 2019 PST Agreement 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.

The OWG approach that was initiated by the Commission to explore issues related to Okanagan Chinook has proven to be a useful forum for bilateral efforts to compile and distill information, provide analyses and recommendations, and identify issues of concern. The OWG made a conscious choice at the onset to expand its participation and recruit and include additional expertise. In this manner, the OWG engaged a breadth of biologists and scientists from across the salmon spectrum in the U.S. and Canada including Fisheries and Oceans Canada (DFO), the Okanagan Nation Alliance (ONA), the Columbia River Inter-Tribal Fish Commission (CRITFC), the Alaska Department of Fish and Game (ADF&G), the Washington Department of Fish and

Wildlife (WDFW), the Colville Confederated Tribes (CCT), and the Oregon Department of Fish and Wildlife (ODFW). Additionally, the OWG brought even more experience to bear by organizing a series of 5 virtual workshops with invited presentations on baseline productivity assessment, bilateral supplementation, escapement, northern pike and survival in order to further explore many of the issues raised in the OWG's first report to the Commission (Matylewich et al. 2019).

Over the course of this process, the OWG has reached a common understanding of the unique opportunities that the transboundary population of Okanagan summer Chinook present to both nations. The OWG concludes that rebuilding the Canadian portion of the population appears to be feasible with a combination of habitat restoration, water management, hatchery supplementation and a robust monitoring program. This report provides recommendations for promoting the mutual, effective conservation of the Canadian portion of the population and maintaining a robust U.S. portion of the population. This report also documents gaps in our knowledge that impede our understanding of the factors that enable Okanagan Chinook to thrive while other populations in the Columbia basin are less successful, and provides recommendations for a program of monitoring, supplementation and habitat restoration that is designed to improve our understanding to ensure a sustainable future for this population in the face of climate change, potential invasion by northern pike and other threats.

This report is the culmination of three years of dedicated effort. It is intended as fulfillment of the initial tasks assigned to the OWG by the PSC in the Terms of Reference (Appendix A) and subsequent annual work plans (Appendix D).

Section 1 provides the background on Okanagan River summer Chinook salmon and its nexus with the PST which resulted in the creation of the OWG in 2019 by the PSC as a forum for bilateral coordination regarding this shared stock. It describes the OWG's tasks and accomplishments.

Section 2 describes the history and current state of the Okanagan system.

Section 3 is organized based upon the life history of Okanagan summer Chinook to identify and communicate the issues and impediments facing their restoration to the Commission, workshop participants, and others involved with the stock's management, habitat, enhancement, conservation, rebuilding and recovery planning. For each life stage, the context and issues or concerns that affect the stock's abundance are described along with potential mitigation options, key knowledge and information gaps, and suggestions for future research.

In Section 4, the Work Group provides advice to the Commission. The Work Group recommends that the Commission consider approaches that build on the value of the existing work group, as the Commission considers ongoing implementation of the provisions of Chapter 3, paragraph 1(d) for Okanagan Chinook. The Work Group foresees several categories of ongoing tasks: providing annual estimates of the metrics needed to implement Chapter 3 (e.g., escapements, exploitation rate), tracking the progress of monitoring, supplementation and restoration efforts for Okanagan Chinook, facilitating the development of biologically-based objectives for the population in both countries, and facilitating the development of a bilateral hatchery supplementation program. Additionally, this section provides a list of recommended projects organized in the following themes: conservation, restoration, hatchery enhancement, and harvest management.

Additional information is available in the appendices, including the OWG Terms of Reference (Appendix A), a detailed list of potential projects and recommendations to aid in rebuilding (Appendix B), the workshop summaries (Appendix C), the OWG annual work plans (Appendix D), and additional data that support the report (Appendix E).

The OWG understands the importance of this healthy natural population as a backbone of fisheries for Indigenous Peoples and for fisheries in the Treaty Area, as a potential donor stock for reintroduction programs, and as a sentinel stock for understanding the impacts of climate change on Chinook populations, merits the continued attention of the Commission.

The pressing issues that the OWG believes need attention now relate to the absence of a coordinated, bilateral enhancement program between the countries. Spawner abundance is extremely low in Canada now, and so very few broodstock can be captured in the Canadian portion of the Okanagan for hatchery purposes. Okanagan summer Chinook smolt production is currently very high at the U.S. hatcheries, ranging from 750,000–950,000 recently, but eggs are only transferred opportunistically to the Canadian kł cp̓əlk̓ stim̓ Hatchery when surpluses are transferred by the U.S. hatcheries. The most suitable donor hatchery in the U.S., the Chief Joseph Hatchery, was not designed for increased amounts of broodstock, and would need modification to provide this. Also, a newly online hatchery, it is still working to consistently meet its production objectives. The combination of U.S. egg transfers and broodstock collection in Canada has resulted in smolt production in the range of 0–42,000 fish annually since 2016. Many aspects of Okanagan Chinook restoration outlined in this report critically rely on hatchery production in Canada, however the lack of shared bilateral objectives and programming for hatchery activities, and adequate facilities is compromising restoration for this population. The OWG believes that a bilateral enhancement program is a priority action that needs immediate attention.

1. INTRODUCTION

The Okanagan[1] River is a transboundary tributary of the Columbia River that supports a relatively large abundance of summer-run Chinook (*Oncorhynchus tshawytscha*) returning to the U.S. portion of the watershed and a much smaller abundance returning to Canada. As such, it has linkages to Chapters 1 and 3 of the 2019 Pacific Salmon Treaty (PST 2020). The summer Chinook in the U.S. portion of the watershed have been remarkably productive recently relative to many other Chinook stocks in the PST area. This is particularly notable considering that the stock must negotiate nine dams on the mainstem Columbia River during its downstream and upstream migrations, and it experiences high predation on migrating smolts, high river temperatures for returning adults, and contributes to fisheries from Southeast Alaska to the Okanagan River. The habitat in the U.S. section of the Okanagan River is relatively intact compared to the Canadian section, which has been dammed and channelized, but considerable efforts are underway to restore the river for Chinook and sockeye (*O. nerka*). While Chinook spawning levels in the U.S. portion of the Okanagan River consistently achieve escapement goals, the Canadian Okanagan has a very small (< 100 on average) returning population of adult summer Chinook. In Canada, Okanagan summer Chinook were assessed as *Threatened* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2006 and re-assessed as *Endangered* in 2017 (COSEWIC 2017). The population is currently under review for listing under the Species at Risk Act (SARA). Additionally, work is underway to develop a rebuilding plan for the stock in accordance with the Canadian *Fisheries Act*.

Both countries have agreed that "*successful Chinook conservation, restoration, and harvest management depends on a sustained and bilaterally coordinated program of resource protection, restoration, enhancement, and utilization*" (PST 2020; Chapter 3, paragraph 1(d)). As such, the Pacific Salmon Commission (Commission; PSC) created the Okanagan Work Group (OWG) in 2019 as a forum for bilateral coordination regarding this shared stock and charged OWG with nine tasks which include summarizing existing information (population structure, factors limiting abundance, productivity and distribution, etc.), management objectives, and identification of opportunities to enhance and improve productivity and abundance (Appendix A).

In 2019, the OWG produced its first report with information for all nine tasks for the Commission (Matylewich et al. 2019), and provided advice to the Commission which informed subsequent work plans:

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; CIG).

[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.

a. Given the complex structure of Mid-Columbia River summer Chinook in the U.S. and the recent recalibration of the Chinook Technical Committee (CTC) 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 section of the Okanagan and would provide fish to assess survival of out-planted juveniles through the Canadian lakes and altered stream sections (both countries presently utilize Passive Integrated Transponder (PIT) tags for similar studies).
3) Establish a bilateral 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.

The OWG's advice to the Commission supported the intent of the 2019 PST Agreement pertaining to Transboundary Rivers, Salmon Enhancement Programs, and Chinook Salmon. The Commission recognized that ongoing work on both sides of the border could be shared to improve the outcomes for Canadian and U.S. Okanagan summer Chinook and that the PST umbrella would be an appropriate bilateral forum for coordination and collaboration. Subsequently, the Commission agreed to maintain the bilateral OWG. Operating under the auspices of the Commission, the OWG provides annual work plans to the Commission for their review and approval in addition to updates on progress towards achieving workplan tasks. The OWG was assigned eight tasks under its 2019/2020, 2020/2021 and 2021/2022 cycle work plans (Appendix D); with the first two focused on annual monitoring and reporting tasks, another on reporting, and the remaining involved convening five virtual workshops with agency and academic subject matter experts to gain information, insights and advice on factors affecting the health of Okanagan Chinook. Summaries from the virtual workshops can be found in Appendix C.

Table 1. Work plan tasks assigned to the OWG from 2020–2022.

Task	Description
1	Report historical and recent escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through 2021.
2	Conduct an exploitation rate analysis for Okanagan summer Chinook with coded-wire tag (CWT) recovery data through 2020 and report the CWT statistics (e.g., mortality distribution tables, survival rates, maturation rates).
3	The Parties recognize the value of creating a baseline assessment of the current productivity and capacity of Okanagan River summer Chinook against which to measure the benefits of future habitat restoration and enhancement actions. The workgroup will coordinate a management entity exploration of alternative approaches to create such a baseline assessment. Alternatives may include a monitoring program for juvenile production, an analysis of spawner and recruit data, the use of habitat-based production models, or other approaches as appropriate.
4	A teleconference with the management entities and others will focus on the potential invasion of northern pike into the Okanagan River. The monitoring and control programs currently happening in the Columbia River upstream of Grand Coulee Dam will be reviewed, and advice will be sought from the management entities and other experts about the steps and methods to prevent the spread of northern pike into the Okanagan River. The findings and recommendations will be summarized for the Commission.
5	A teleconference with the management entities and others will review the current escapement monitoring programs that the management entities use for summer Chinook in the U.S. and Canadian sections of the Okanagan River. The current escapement estimates will be reviewed relative to the CTC bilateral data standards for Chinook escapement indicator stocks. Any new escapement methodologies will be communicated to the OWG and other for review and feedback on study design recommendations that could help the management entities achieve these CTC data standards and summarize them for the Commission.
6	A teleconference with the management entities and others will focus on the potential survival issues for juvenile and adult summer Chinook in the U.S. and Canadian sections of the Okanagan River. The current survival monitoring projects relative to these issues will be reviewed and examined to identify any gaps or modifications to existing study designs to learn about locations where the Okanagan summer Chinook may be experiencing poor survival. Findings and recommendations will be summarized for the Commission.
7	A teleconference with the management entities and others will review the current escapement monitoring programs that the management entities use for summer

Task	Description
	Chinook in the U.S. and Canadian sections of the Okanagan River. The current escapement estimates will be reviewed relative to the CTC bilateral data standards for Chinook escapement indicator stocks. Any new escapement methodologies will be communicated to the OWG and others for review and feedback on study design recommendations that could help the management entities achieve these CTC data standards and summarize them for the Commission.
8	The OWG will develop a synthesis report to formally document hosted workshops, identify issues and impediments to Okanagan Chinook restoration, and recommended next steps.

This report, identified in task 8, is organized based upon the life history of Okanagan summer Chinook to identify and communicate the issues and impediments facing their restoration to the Commission, workshop participants, and others involved with the stock's management, habitat, enhancement, conservation, rebuilding and recovery planning. For each life stage, the context and issues or concerns that affect the stock's abundance are described along with potential mitigation options, key knowledge and information gaps, and suggestions for future research. The report includes advice to the Commission on next steps and recommendations.

2. History and current state of the Okanagan system

2.1 Historical context

Prior to the arrival of settlers and the extensive alterations to the watershed, Chinook salmon clearly thrived throughout the accessible reaches of the Okanagan system. Historically, Columbia River Tribes were wealthy people because of a flourishing trade economy based on salmon (CRITFC 1995). Celilo Falls was a major trading place for tribes in the western United States. Summer Chinook were abundant enough to provide for subsistence and commercial fisheries for many years, until abundance declined severely, and by 1964 fishing was limited to subsistence purposes only. By the 2000s, the abundance of summer Chinook increased enough to allow for commercial fisheries. *Ntytyix* (Chief Salmon) was and continues to be a primary food mainstay of the *Syilx Okanagan* peoples and central to their culture and trade traditions (Okanagan Nation Alliance, n.d.). A myriad of *Syilx Okanagan* cultural practices demonstrate *snxa?l'iwlem* (honouring the sacredness of the river) while reinforcing strong cultural-spiritual ties between *Syilx Okanagan* communities and the salmon. As one of the Four Food Chiefs of the *Syilx Okanagan* people, salmon are not only a form of sustenance, they are a relative, and an essential part of the continued resilience of the *timix^w* (all living things). As such, these salmon are central to a wide range of connections between generations, communities, humans and non-humans, terrestrial and aquatic species and transboundary watersheds.

Syilx Okanagan historical knowledge describes two distinct runs present in the Okanagan watershed: *ntitiyx* (spring Chinook) arrived in early summer (May–July) and *sk'lwis* (summer Chinook) arrived in late summer to fall (August–October) (Armstrong 2015). Historically, these

Chinook runs provided for abundant food fisheries and trade for the *Syilx Okanagan* people. Prior to dam construction in the Canadian Okanagan watershed, there were many Chinook fishing areas located throughout the Okanagan River and they were plentiful and easy to harvest. Historic Chinook fisheries took place in August and September at the outlet of Okanagan Lake, at Okanagan Falls, and at McIntyre bluff (Ernst and Vedan 2000).

2.2 CURRENT STATE OF THE OKANAGAN SYSTEM

The Okanagan River is the only portion of the Canadian Columbia River drainage currently accessible to salmon. The river begins in British Columbia and flows southward from the southern end of Okanagan Lake for more than 200 km to enter the Columbia River near Brewster, Washington (WA) (Figure 1). In Canada, the Okanagan River historically was a meandering river that flowed from Okanagan Lake to Osoyoos Lake within a wide, unconfined valley with broad and active floodplains (Gaboury 2004). As urban settlement concentrated along the river mainstem, widespread flooding led to diking, narrowing, and channelization of 84% of the river in the 1950s, decreasing the river length by 50% (Bull 1999; Bull et al. 2000; NPCC 2004).

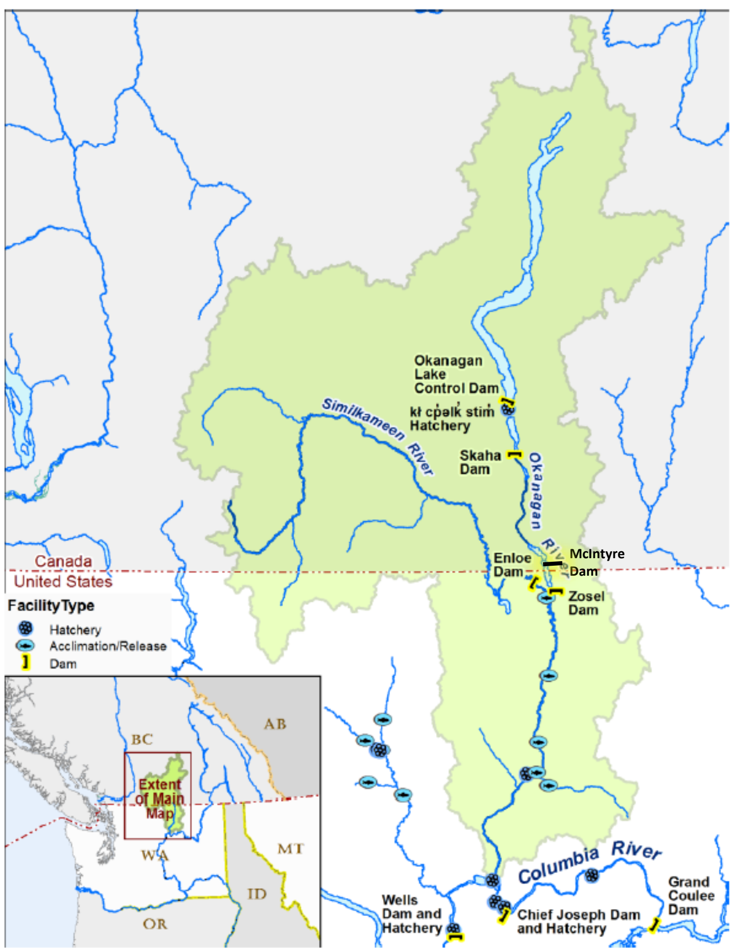

Figure 1. Map of the Okanagan and Columbia Rivers (adapted from Matylewich et al. 2019).

The 16 km long river section between Osoyoos Lake and the Town of Oliver, BC is entirely channelized with dikes on each side (Figure 2). To compensate for the shortened channel and increased gradient, 17 vertical drop structures (VDS) were installed. The section has sandy substrate and contains relatively little suitable Chinook spawning habitat except for a 30–50 m zone near each VDS where suitable substrates for spawning and egg incubation accumulate. Most of the remaining river in Canada (McIntyre Dam northward) is also channelized but contains coarser substrate with some suitable spawning areas. Only 16% of the river in Canada remains in a natural or semi-natural state (Rivard-Sirois 2020), resulting in significant losses in aquatic and riparian habitat. Between Oliver and McIntyre Dam is an 8-km reach with natural or semi-natural channel conditions and high-quality spawning habitat. These are the primary spawning areas for Okanagan summer Chinook in Canada.

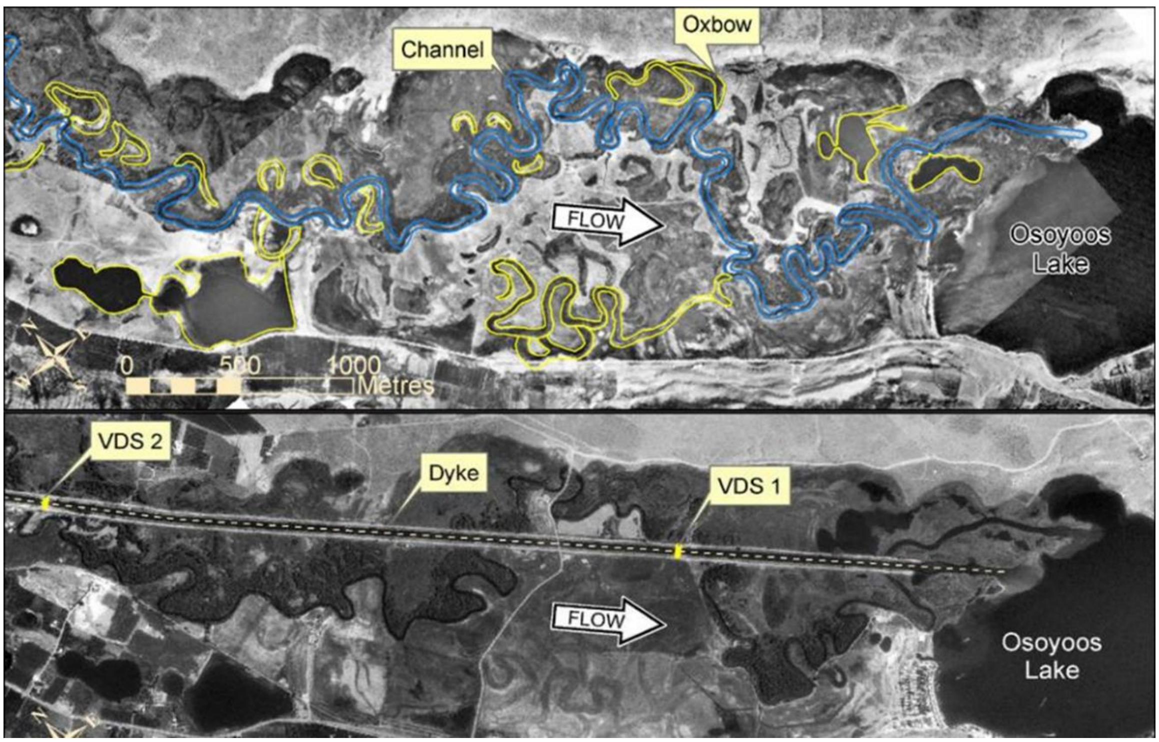

Figure 2. Okanagan River upstream of Osoyoos Lake prior to (top) and after (bottom) channelization.

In addition to the flood control measures, three new dams were constructed at the outlets of Okanagan Lake, the outlet of Skaha Lake, and between Vaseux Lake and Osoyoos Lake (McIntyre Dam) for water storage and flood control (Figure 1). The constructed dams were not passable to upstream migrating fish, and anadromous salmon that once migrated as far north as Okanagan Lake and its tributaries were limited to areas downstream of McIntyre Dam for the next six decades.

The Okanagan Lake Regulation System encompasses the VDS structures, dams and dikes in the Canadian Okanagan River. Northwest Hydraulic Consultants Ltd. (NHC 2020) provided updated flood elevations for the Okanagan valley, with consideration of climate change impacts during the 21st century. The results indicate a significant increase in flood elevations in the valley bottom even if greater winter outflow from Okanagan Lake is permitted. Thus, the system requires modernization and changes to accommodate the projected change in flow volumes.

Several river restoration projects have already been conducted along the Okanagan River to assist in the recovery of fish stocks and have returned portions of the channelized river back to more natural conditions to create more complex and diverse habitat for fish and wildlife. The Fish Water Management Tool improved the management of water within the Okanagan watershed for the benefit of fish, by stabilizing flows during the spawning and incubation period (Machin et al. 2018).

As part of the effort to restore dwindling fish populations and the ecological values of the Okanagan River, dams along the Okanagan River were retrofitted one-by-one to restore fish passage. In 2009, the ONA Fisheries Department completed a gate retrofit at McIntyre Dam, opening fish access up to the outlet of Skaha Lake, including an additional 7 km of Okanagan River mainstem habitat, Vaseux Lake, and one major tributary. In 2014, modifications to the Skaha Lake outlet dam opened fish access to the outlet of Okanagan Lake, including Skaha Lake and 6 km of mainstem habitat upstream, as well as three major tributaries. In 2019, partial fish passage was restored at the Okanagan Lake outlet dam, which enables anadromous access into the majority of their historic range. However, modifications to the fish ladder are required to allow passage over the full range of flow conditions.

On the U.S. side of the border the Okanagan River flows approximately 125 km south to its confluence with the Columbia River. Zosel Dam, at the outlet of Osoyoos Lake has a fish ladder that allows passage of adult Chinook into Canada, whereas Enloe Dam (rkm 14) on the Similkameen River restricts passage of adult Chinook to Canada. From its confluence with the Okanagan River near the town of Oroville (rkm 119) upstream to Enloe Dam, the Similkameen River also contains important Chinook pre-spawn holding and spawning grounds. The Okanagan River in the U.S. has had considerable riparian and floodplain alteration, but the extent of channelization is not as comprehensive as in Canadian reaches. The U.S. Okanagan has had fairly robust summer Chinook spawner escapements for several decades, aided by a supplementation program that uses mostly natural-origin broodstock to support conservation and harvest objectives.

2.3 History and overview of enhancement programs

2.3.1 U.S. 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 occurred 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 annually. 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 Tribes developed a method of using a purse seine to collect natural-origin broodstock at the mouth of the Okanagan and since 2010 the program's broodstock has been approximately 90% natural-origin fish from the Okanagan (Pearl et al. 2022). The Similkameen Pond program is now a component of the Chief Joseph Hatchery integrated program and the release target is up to 400,000 yearling smolts (or 50% of the yearling program).

The Chief Joseph Hatchery 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 Chief Joseph Hatchery 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 when the release programs are fully achieved 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 effects. 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.

2.3.2 Canadian enhancement programs

The kł cp̓əlk̓ stim̓ Hatchery, run by ONA in Penticton, began operations in 2014 focusing on sockeye salmon. The hatchery began releasing Chinook in brood year 2016 with a release group of just over 10,000 subyearling fry. Since the Chinook program's inception, approximately

92,901 summer Chinook fish have been released. A portion of these fish were released with adipose fin clips and PIT tags (56,149), and a smaller portion with adipose fin clips and CWTs (3,383). The kł cp̓əlk̓ stim̓ Hatchery collects broodstock from the Canadian portion of the Okanagan River when possible. Two to three fish were collected in 2017 and 2020 and the hatchery has been cryopreserving Chinook milt since 2016. However, brood collection in Canada to date has been limited by low spawner abundances and most eggs have been provided by Chief Joseph Hatchery. Since 2016, between 0 and 46,000 summer Chinook eggs from Chief Joseph Hatchery were transported to Canada annually. The objective for the Chinook Conservation Hatchery Program in Canada is to increase abundance to rebuild the stock and have Chinook recolonize habitats that were previously inaccessible due to irrigation and flood control dams in Canada. The first phase of this program includes a hatchery supplementation target of >250,000 eggs. Targets are anticipated to be revised as additional information on survival of the released fish becomes available.

3. OKANAGAN SUMMER CHINOOK LIFE HISTORY

Okanagan summer Chinook have ocean-type life history and they are closely related to the other ocean-type populations originating from the Columbia mainstem and tributaries upstream of the Snake River (Myers et al. 1998). The ocean-type Chinook that formerly spawned above Grand Coulee Dam pre-1938, in Canadian and U.S. waters, were apparently similar genetically and in life history attributes. Typical of ocean-type Chinook, Okanagan summer Chinook show considerable plasticity in several stages of their life history, including predominantly subyearling outmigration strategies, a broad range of ages at maturation and return, and apparently even some amount of residualization.

3.1 EGG TO FRY

Survival from egg to fry for salmon species can be affected by oxygen levels, water levels, the amount of sedimentation, and any physical impacts from scouring due to ice, debris, or high water flows while eggs and alevin reside in gravel. Since no egg incubation studies for Okanagan Chinook salmon exist to date, Okanagan River sockeye egg incubation studies can be used as a proxy as they are expected to experience similar environmental conditions during this life stage (see Figure 3 for photo of in situ egg baskets). The results of these studies indicate that oxygenation levels are not considered a concern in the Okanagan River at present. Generally, the Okanagan River has high oxygenation (9–13 ppm) and developmental issues can occur at levels at or below 6 ppm, and survival issues at 4 ppm or lower.

As the region was settled, the river was channelized (straightened) to support agriculture, flood control, roads and other infrastructure. Removal of the river's natural meander resulted in a homogenous environment with sandy substrate as opposed to gravel that is found in more heterogeneous environments. The channelization efforts also included rip-rap river banks throughout much of the Okanagan River, which reduces natural gravel recruitment and limits potential spawning, rearing, and riparian habitat. Channelized portions of the river exhibit reduced sockeye egg-to-fry survival, but survival has improved with efforts to re-naturalize the river. Increased sedimentation and macrophyte growth occur in the channelized sections resulting in less oxygenation of eggs and are hypothesized to be the most likely factors contributing to reduced egg survival in these reaches (Appendix C; Survival Workshop). Black egg disease on sockeye eggs was more prevalent in channelized reaches of the river and is assumed to be from the increased presence of Eurasian water milfoil (*Myriophyllum spicatum*) and its tendency to trap fine sediment. These studies indicate that channelized reaches exhibit egg survival estimates of 30–50%, while the semi-natural reaches have estimates of 60–70% survival. Furthermore, the Okanagan River Restoration Initiative (ORRI) restored several channelized sections of the river to a more natural state and increased egg to fry survival by an estimated 70–80% (Appendix C; Survival Workshop). This increase in survival can largely be attributed to different rates of sedimentation between reaches. Sedimentation in channelized sections is greater than 5%, in natural areas of the Okanagan River it is 2% and in restored portions sedimentation was determined to be less than 1% (Appendix C; Survival Workshop). A summary table of these values is presented below (Table 2).

Figure 3. In situ egg baskets for sockeye egg survival studies performed by the Okanagan Nation Alliance.
Note: Photo credit Kari Alex.

Table 2. Summary of sedimentation rates and egg survival rates by river condition.

River Condition	Sedimentation Rate	Egg Survival Rate
Channelized	>5%	30-50%
Semi Natural	2%	60-70%
Restored	<1%	70-80%

These studies demonstrate the strong need for further habitat restoration in the Canadian Okanagan River to improve the survival and productivity during this life stage. Management entities can inventory sediment sources, then identify mitigation options, such as sediment traps to reduce the influx of sediment to the Okanagan River from its tributaries. There are currently two sediment traps in tributaries of the Canadian Okanagan River at Shuttleworth

(Figure 4) and Ellis creeks. They are moderately successful at retaining sediment but require ongoing maintenance to remove accumulated sediments and are unable to capture the smallest sediment size fractions (K. Alex, pers. comm.). Information regarding sedimentation rates and sources in the U.S. portion of the Okanagan River is not currently available.

Figure 4. Sediment trap at the mouth of Shuttleworth Creek near its confluence with the Okanagan River.

In addition to sedimentation, channelization decreases the resiliency of the river to accommodate major flooding events which can negatively impact egg to fry survival through scouring. The Okanagan Basin has a Fish and Water Management Tool (FWMT) which is used for promoting sockeye salmon and kokanee production in Okanagan, Skaha and Osoyoos lakes, though other fish species are considered. The FWMT is a coupled set of biophysical models of key relationships (climate, water, fish, and property) used to predict consequences of water management decisions for fish other water uses. Although no FWMT studies have been done directly on Chinook in the Okanagan River to date, the benefits of the FWMT likely extend to Chinook, as they spawn at similar locations and times as sockeye. The FWMT improves the water management decisions that lead to increased sockeye fry production by reducing density independent losses due to variations in the amount and timing of controlled river discharge. In 1982, the Okanagan Basin Agreement outlined sockeye-friendly flows for the FWMT to assist in making water release decisions at the Okanagan Lake dam. Flood, scour, and desiccation events can be better controlled with the FWMT. ONA has undertaken flood assessments and work is ongoing to include potential impacts of extreme events due to climate change (such as those that occurred in 2021) into the FWMT model (Figure 5). These impacts are likely to occur in the future; thus, it is prudent to develop plans that can be implemented when flow scenarios arise that can negatively impact survival of salmon species. Relocating dikes farther back from the stream channel in key locations will enable the river to naturally accommodate and mitigate potential flooding and subsequent scouring events. Although this option has limitations due to development in the area, the existing system of dikes will need to be upgraded as they were not designed to accommodate the hydrological conditions that are being predicted under anticipated climate change scenarios. This will provide an opportunity to include salmon ecosystem restoration in the redesign of the water management system. Reintegrating meanders should also increase environmental heterogeneity, habitat diversity and improve gravel recruitment to the Okanagan River.

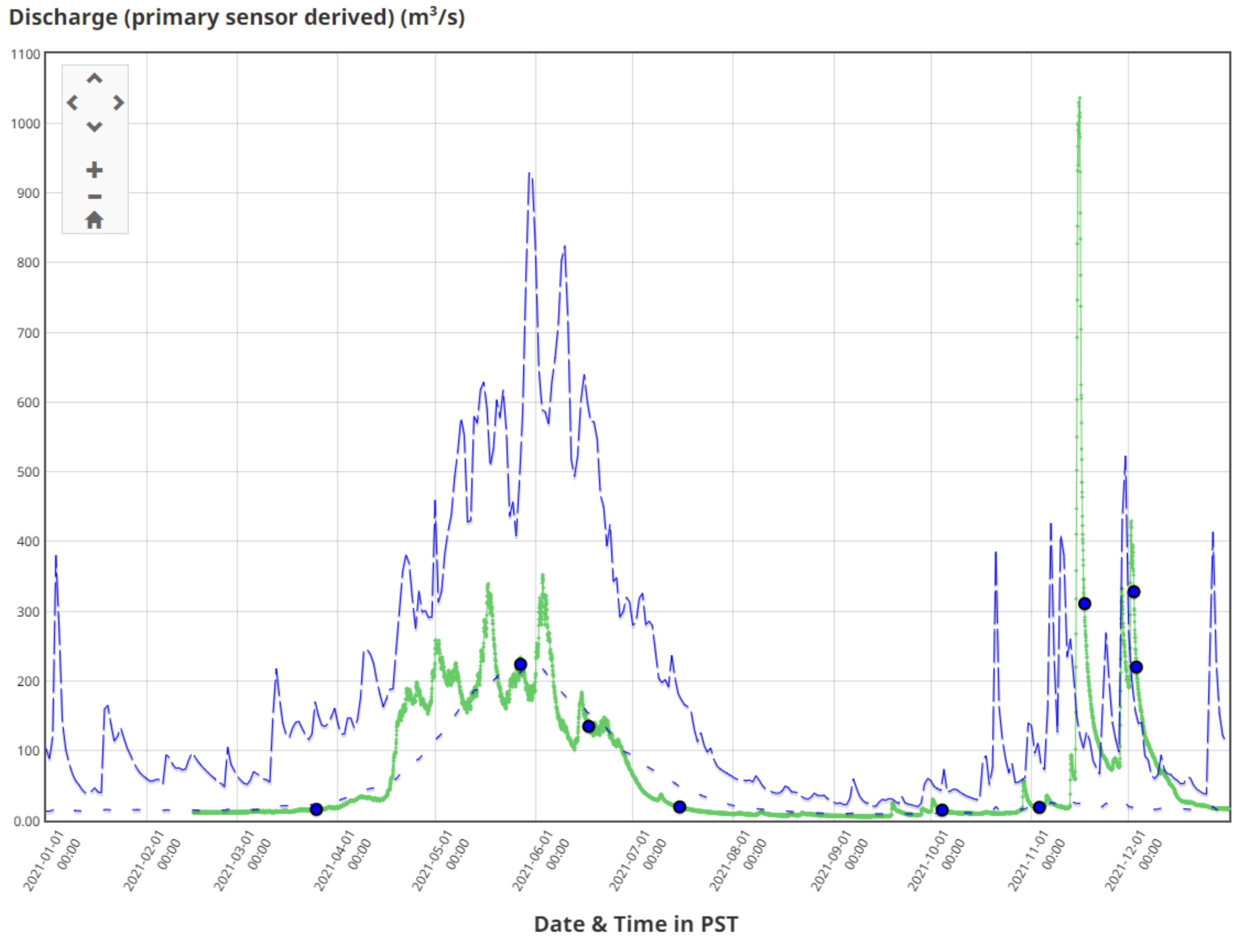

Figure 5. Example of the extreme flood event in the Okanagan Basin during November 2021 (green series) relative to the historic maximum (long blue dash series) and mean daily discharges (in cubic meters per second), over 1965–2000 (Water Survey of Canada Station 08NL038 – Similkameen River near Hedley).

The survival workshop hosted by the OWG in July 2021 enabled members of the OWG to discuss and improve their understanding of how different life stages are negatively affected by issues throughout the Okanagan River. Several key knowledge gaps and areas of further study became apparent. For example, we know that there are observed changes in body size-at-age, but we do not know the impact that this change may have on redd structure and location, and how that subsequently might contribute to incubation success or failure. Additionally, the effects of climate change are expected to be particularly noticeable in the Okanagan River, but we lack information on the impacts of warming stream temperatures on egg incubation timing and how this ecological mismatch might impact emerging fry. Chinook specific egg survival information is currently lacking in both the U.S. and Canada and no studies on other salmonids have been conducted in the Okanagan River in the U.S. Consequently, there is no Okanagan basin specific information regarding sedimentation levels, rates, or sources.

The OWG has determined that low egg to fry survival rates are a likely impediment to recovery of the Canadian portion of the population and that habitat restoration is a key element to improving egg to fry survival.

3.2 Fry to Smolt

Fry to smolt survival refers to survival from newly emergent fry to smolts that commence outmigration to the ocean. During this period, fry reside in the Okanagan River and lakes in Canada and the U.S. Information on habitat use and behavior of Okanagan Chinook during this life stage is limited, but some information exists from releases of tagged hatchery fish and incidental observations during fisheries surveys and monitoring projects in these areas.

The ONA has released PIT tagged hatchery Chinook from the kł cp̓əlk̓ stim̓ Hatchery in Penticton since 2017. Juvenile survival data for hatchery fish released in the Canadian Okanagan is available from releases in 2017 (subyearling), 2019, 2021 and 2022 (yearling) and is presented in Table 5. Survival from these releases to Rocky Reach Dam has ranged from 4.2% to 26% (average 18%). However, there is evidence from PIT-tag detections, creel surveys and Indigenous Knowledge that some of the hatchery and natural Chinook rear for extended periods or residualize in freshwater; the prevalence of this behavior is not yet known. PIT-based finer scale survival estimates for areas in the Canadian Okanagan (e.g., through Osoyoos Lake) vary widely between release groups and are less reliable due to low juvenile detection probabilities at individual PIT arrays. Improvements in juvenile detection efficiencies at the PIT arrays, where possible, would improve the precision of reach-scale survival estimates in Canada. An acoustic telemetry survival study for hatchery subyearlings is currently underway but results are not yet available. PIT and acoustic telemetry studies will be helpful to identify temporal or spatial sources of mortality, critical habitats, and fish behavior. Issues and concerns related to Okanagan Chinook fry to smolt survival were identified through the workshops hosted by the OWG and are described in the following sections.

3.2.1 Loss of rearing habitat

One of the most pressing concerns identified is the loss of Chinook rearing habitat in the Canadian Okanagan River resulting from channelization. Chinook fry typically use off-channel habitats such as floodplains and side channels for rearing, especially during the spring. Channelization of the Okanagan River has eliminated most of these river and riparian habitats, with only short sections of the river remaining in a natural (3 km) or semi-natural (2 km) state. The remainder of the river in Canada has been excavated, straightened and surrounded by dikes, cutting off connection to off-channel areas and riparian habitats. An assessment of off-channel rearing habitats in the Canadian Okanagan River revealed that approximately 4% of potential off-channel rearing space is fully accessible to Chinook fry (some of this was made accessible through restoration projects); 65% has very limited or partial connection via small diameter culverts through the dikes; and 31% is inaccessible with no connection to the mainstem river (McGrath et al. 2022). Approximately 50% of the original river length was removed as a result of channelization and most of the remaining river is homogenous and lacks complexity for salmon ecosystem function and productive fry rearing.

Habitat restoration is the primary mitigation option to address rearing habitat loss. Several restoration projects have already been completed and restored access to meanders, side channels, and floodplains in Canada. Additional restoration work is needed to reconnect side channels and flood plains disconnected by the dikes. Other options to restore salmon ecosystem function in the mainstem river channel include dike setback, dike removal, riparian restoration and creating habitat complexity where possible. The necessary modernization of the Okanagan Lake Regulation System provides a key opportunity to make fish friendly modifications to the existing channel configuration and flow control structures.

3.2.2 Flow control infrastructure

The flow control infrastructure of the Okanagan River and lakes in Canada and the U.S. present a possible source of mortality and migration delays for Chinook fry. Most dams on the mainstem Okanagan River lakes have undershot gates; however, juvenile salmonids typically migrate in the upper part of the water column (Davidsen et al. 2005; Evans et al. 2001). This results in migration delays while fry and smolts attempt to find the location of the undershot gates at depth. Migration delays increase the duration that juvenile Chinook are exposed to predation by piscivorous birds and native and non-native fish in the dam forebays. In addition, studies conducted at McIntyre Dam prior to gate modification revealed injuries of sockeye smolts captured below the dam, including descaling, body lesions, damaged eyes and severe cuts (Rivard-Sirois and Long 2009). The high number of stationary PIT tags in the vicinity of Zosel Dam, that were previously applied to Chinook released in Canada, indicate high mortality near this flow control site.

The 17 VDS along the channelized sections of the Okanagan River consist of low-head weirs. Studies have shown that surface-orientated fishes migrating downstream can be markedly impeded and have reduced survival by passage through low-head weirs, and that the effects are exacerbated by low-flow conditions (Gauld et al. 2013). Juveniles may be disoriented by turbulent conditions and recirculation currents immediately below the structures and may become more susceptible to predation in these areas. The magnitude of migration delays and juvenile Chinook mortality associated with VDS is unknown but could be a critical survival bottleneck that warrants further investigation. Further studies on migration delays at dams and VDS are recommended.

The diked river sections present an additional concern where side channels are partially connected to the Okanagan River channel through small diameter culverts. The culverts are either open or regulated via sluice gates to control the inflow. Sluices are common on side channels managed by the province of BC as part of the South Okanagan Wildlife Management Area (SOWMA). Chinook fry have been observed migrating on the margins of the Okanagan River and seeking shelter from the current in concrete structures surrounding culvert intakes to the side channels. They enter some of the side channels either voluntarily or become entrained by strong currents at the entrance of the culverts (McGrath et al. 2022). The outlet of these side channels reconnects to the main channel via outlet culverts passing back through the dike.

These outlet culverts are frequently clogged by accumulating debris, and most outlet culverts have metal flap gates that are closed or only slightly open to maintain higher water levels for the side channels. Most of the side channels are relatively stagnant with low current, and some are interrupted by berms or water intake structures. These conditions likely result in fry becoming stranded and not contributing to adult production. Entrainment rates and fry mortality in these areas is unknown and were identified as a knowledge gap. It is recommended that the operation of the SOWMA sluice system at side channel in- and outlets be reviewed and that adjustments to sluice operation are explored to reduce the likelihood of Chinook fry entrainment.

The necessary modernization of the Okanagan Lake Regulation System provides a key opportunity to alter existing flow regulation structures such as dams, dikes and VDS with fish friendly modifications. Dams should be designed to enable fish passage as fast as possible with priority given to surface level rather than bottom pathways. Examples include removable spillway weirs, and installation of overshot gates instead of undershot gates. This would reduce migration delays and potentially reduce smolt injuries and predation around dams. VDS can be backwatered through riffle construction, which was already completed at VDS 17 below Okanagan Falls. Inlet and outlet culverts that connect side channels behind dikes with the mainstem river need to have improved connectivity to reduce the risk of entrainment and stranding. Full reconnection of side channel habitats is preferred to restore off-channel rearing areas.

3.2.3 Water temperatures

A portion of Okanagan Chinook fry rear in the river or the mainstem lakes in Canada for several weeks to months prior to outmigration and redistribution in the watershed as determined from the PIT-tag data and fish sampling and monitoring. During this time, water temperatures in the river and the epilimnion of the lakes periodically exceed salmonid thermal tolerances. The relationship between smolt outmigration timing, survival and warming waters in the Okanagan is complex and not well understood and could be an important bottleneck for Chinook in the Canadian Okanagan. Water temperature in the south basin of Osoyoos Lake typically averages 22°C by early July, and smolt emigration may not be successful if juvenile Chinook are delayed by a thermal barrier in the lake. The U.S. component of the population emigrates from the Okanagan River from late April to June, based on rotary screw trap (RST) and beach seine data that show the fish arrive at the Columbia River before the Okanagan River temperatures at Mallott, WA reach 20°C (Figure 6). The continued application of PIT tags to Chinook released in Canada and the U.S. is recommended to understand juvenile and adult migration timing and survival relative to flow and temperature.

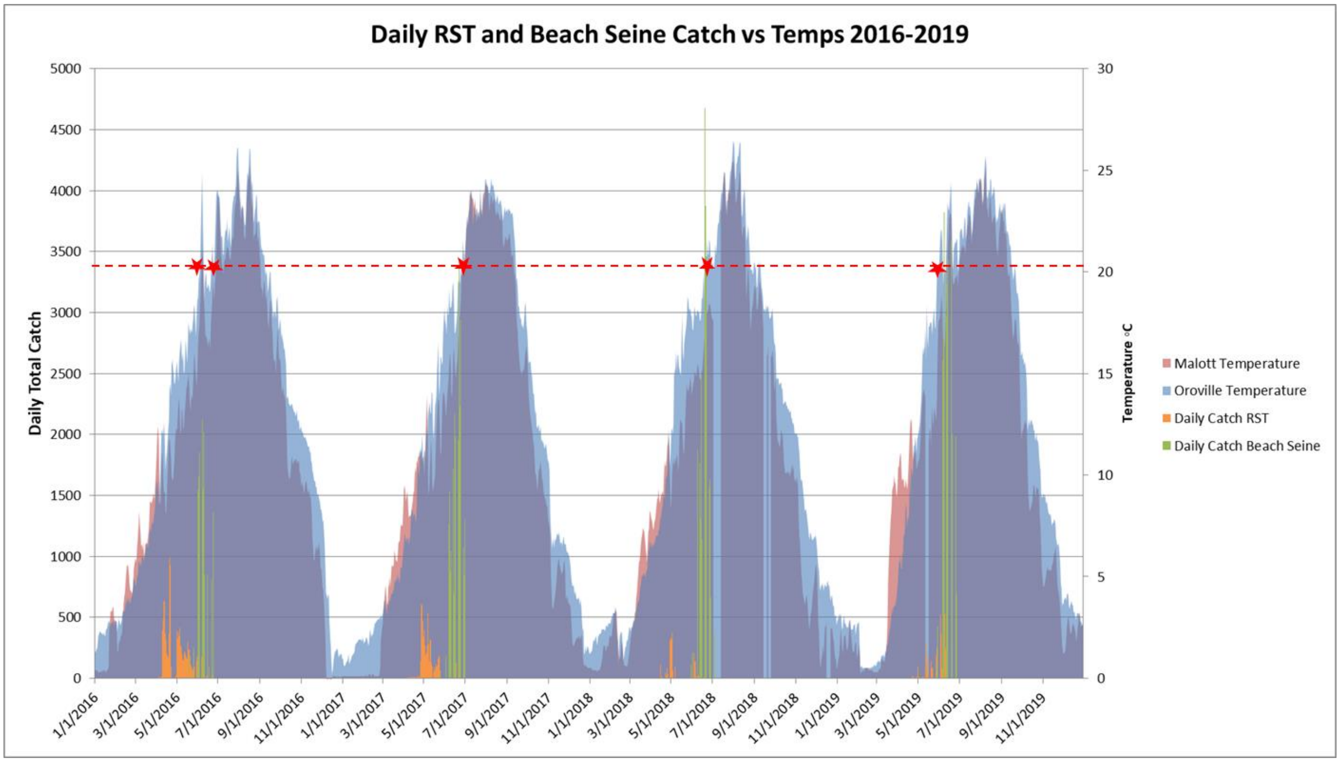

Figure 6. Juvenile Okanagan Chinook caught with a Rotary Screw Trap (RST) and beach seine with Okanagan River temperatures at Oroville, WA and Malott, WA by day from 2016 to 2019. Note: The duration of sampling is intermittent due to river conditions and season. Data provided by Colville Confederated Tribes (CCT) Fish and Wildlife Program.

Possible mitigation options for water temperatures are limited. Increased shading through re-establishment of tall riparian vegetation such as Black Cottonwoods would result in lower solar heat inputs for the mainstem and side channels, however revegetating the dike sections may be more challenging due to concerns about woody debris accumulation and erosion during high flows which could affect dike integrity. Alternatively, dike setbacks would reconnect natural floodplains with space to support riparian trees and shrubs and improve salmon habitat quality. Another potential mitigation option is a hypolimnetic syphon that would draw water from deeper, colder areas of one of the mainstem lakes and transport the water to below the outlet dam for release during temperature sensitive periods. This concept was explored for Skaha Lake but requires further investigation into feasibility and cost. Many of the tributaries supply cool water to the Okanagan, however irrigation diversions and extractions from these tributaries reduce the potential volume of cool water entering the Okanagan River. Changing the point of water extraction, for example from the tributary to a ground water source, during temperature sensitive periods of the year is another option to mitigate high water temperatures by increasing the supply of cool water, and it can provide local thermal refugia for juvenile and adult Chinook. The Similkameen River is a large cool water source that joins the mainstem of the Okanagan River near Oroville, WA. However, the thermal relief provided by the Similkameen River does not extend completely downstream to the Columbia River throughout the summer; thus, outmigrating smolts will experience thermal stress or migration disruptions unless they reach the Columbia River by early July.

An additional concern related to temperature is the occurrence of a temperature-oxygen squeeze in Osoyoos Lake during the summer months, characterized by low dissolved oxygen in the hypolimnion of the lake and high water temperatures in the epilimnion. During some years, this leaves a narrow band of conditions suitable for juvenile Chinook rearing and migration. This phenomenon is typically more pronounced in the shallower south basin of Osoyoos Lake and may periodically present a migration barrier to fry, but it often develops during July after smolts have emigrated from the lake. Currently, no feasible options have been identified to mitigate the temperature-oxygen squeeze in Osoyoos Lake.

3.2.4 Predation

Predation by non-native piscivorous fish in the Canadian lakes, in the Okanagan River and in the area backwatered by Wells Dam (Lake Pateros), was identified as a major concern. Exotic predatory species in Okanagan valley lakes include largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*) and potentially yellow perch (*Perca flavescens*). These species make extensive use of shallow littoral areas that are used by Okanagan Chinook for rearing. Possible mitigation efforts include measures aimed at suppressing the abundance of these species (Loppnow et al. 2013). Targeted communication to anglers and reward programs could be used to encourage targeting of invasive species in addition to maintaining and/or further liberalize warm water daily bag limits. Available spawning habitat and spawning success for these species could be reduced by removing Eurasian water milfoil and potentially drawing down Vaseux Lake during key bass and other non-native spawning periods to reduce the amount of available vegetated littoral areas, and ultimately reduce the abundance of and predation by non-native fishes. Predator abundance surveys would provide a baseline to inform targeted removal and suppression programs.

A key concern is the potential for the spread of northern pike (*Esox lucius*) from its current distribution in Lake Roosevelt above Grand Coulee Dam. If they spread downstream in the Columbia River, there is a high potential for invasion into the Okanagan River. Northern pike are generalist feeders but are reported to target salmonids where their ranges overlap (Cathcart et al. 2019; Sepulveda et al. 2014). Their impact on the local fish community in some invaded areas of Alaska has been severe, resulting in a complete loss of salmonids and other native species (Dunker et al. 2018). The primary concern related to their invasion is predation of Chinook fry and smolts in the Okanagan River, Okanagan and the mainstem Columbia River downstream of the Okanagan River confluence. Habitat in the Okanagan is very suitable for northern pike with abundant warm, shallow, weedy littoral habitats. Their establishment in the Okanagan is highly likely once they invade, which will likely reduce survival and abundance for Okanagan Chinook based on experiences in Alaska (e.g., Dunker et al. 2018).

Prevention of northern pike invasion is the most effective approach followed by rapid response when any northern pike are detected in the Okanagan basin. Prevention activities include outreach to angler clubs, signage at boat launches, establishing penalties for moving northern pike, communication in fishing regulations and while purchasing fishing licenses, during fishing tournaments, fisheries field surveys, and via social media. Natural dispersion can possibly be prevented through barrier installation, but this may prove challenging in areas with high numbers of anadromous and migratory species like the Okanagan.

Monitoring programs are needed to alert multiple fisheries management entities of the spread of northern pike into the Columbia River below Chief Joseph Dam and into the Okanagan River. Monitoring approaches include environmental DNA (eDNA) sampling, gillnetting, fyke netting, and electrofishing. The Colville Confederated Tribes (CCT) have a well-established monitoring program and the ONA is beginning to monitor through eDNA sampling in Osoyoos Lake. However, it is unclear if the current monitoring program is adequate to detect pike presence in the Okanagan River quickly enough to prevent an invasion. A transboundary eDNA coordination call is recommended to coordinate eDNA sampling among agencies and to determine gaps in the current sampling programs to improve the early detection network.

A spatial database of likely population extent informed by eDNA sampling, angler reports, and gill netting and electrofishing data would inform monitoring and response. This would require coordination between agency databases. A coordinated monitoring and response plan among the Tribal and First Nations fishery managers, the state, provincial and federal fisheries agencies, and invasive species councils should focus on aligning detection monitoring activities and communication plans to facilitate a rapid response when northern pike are found in the Okanagan.

If northern pike become established, suppression programs are needed such as those used in other areas consisting of gill netting, electrofishing, and seining during spawning periods; eradication via rotenone in small, contained water bodies; and angler incentive programs such as bounties (Massengill et al. 2020). A suppression program in the Pend Oreille River was effective at reducing pike abundance, but it is unclear if it can be effective in larger systems such as the Okanagan and Columbia rivers. After an initial higher effort, ongoing maintenance is required to maintain low abundances. Geographic information system (GIS) mapping is used to identify areas to target for netting efforts.

3.3 SMOLT EMIGRATION

Juvenile Okanagan summer Chinook must navigate through nine mainstem Columbia River dams in the U.S. en route to the ocean. The five uppermost dams are operated by Public Utility Districts (PUDs) and the next lower four dams are federally operated by the U.S. Army Corps of Engineers. Modifications to the operating procedures of these dams over several decades have greatly improved juvenile passage and survival. However, these dams and the reservoirs they create still contribute to a large portion of mortality during the smolt emigration life stage. In the section below, we summarize the current state of knowledge of passage and survival of juvenile Okanagan summer Chinook through the mainstem Columbia River.

3.3.1 U.S. Okanagan studies

Approximately 8,000–25,000 natural-origin subyearling Chinook are PIT tagged and released annually by the CCT in the U.S. Okanagan River near its confluence with the Columbia River. Further, approximately 5,000 subyearling hatchery Chinook from the Chief Joseph Hatchery segregated program and 5,000 from the Omak Pond integrated program are PIT tagged annually. In addition, approximately 5,000 each of segregated and integrated hatchery yearling releases are tagged.

Yearling summer Chinook released from Omak Pond from 2015–2021 have average survival of 0.63 (range 0.54–0.80) to Rocky Reach Dam and 0.47 (range 0.37–0.63) to McNary Dam (Table 3). These average survivals are slightly less than estimates from nearby programs but are within a similar range.

For subyearling summer Chinook released from Omak Pond from 2015–2021 average survival is 0.46 (range 0.37–0.70) to Rocky Reach Dam and 0.28 (range 0.14–0.48) to McNary Dam (Table 4). These subyearling survival estimates are considerably less than the yearling survival estimates. Survival of natural-origin subyearling summer Chinook collected from the beach seine at the mouth of the Okanagan is less than the estimates for hatchery origin fish. Survival of other subyearling summer Chinook from nearby programs are also shown in Table 4. Survival estimates of Wells Hatchery subyearling summer Chinook extend as far back as 1997 and are available from the Fish Passage Center (Fish Passage Center 2022).

All survival estimates were obtained from Columbia River Data Access in Real Time (DART) (Columbia Basin Research 2022).

Table 3. Yearling survival (generated via DART CJS) for hatchery summer Chinook released from various locations to Rocky Reach and McNary dams, 2015–2021.

Note: The Chief Joseph Hatchery Segregated Program is indicated by CJH segr. and the Similkameen Program is indicated by Similk.

Summer Chinook Yearling Release Group																
	Survival to Rocky Reach Dam								**Survival to McNary Dam**							
Release Year	**CJH segr.**		**Omak Pond**		**Similk.**		**Carlton Pond**		**CJH segr.**		**Omak Pond**		**Similk.**		**Carlton Pond**	
	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr
2015	0.71	0.04	NA	NA	NA	NA	0.63	0.02	0.68	0.14	NA	NA	NA	NA	0.55	0.10
2016	0.78	0.04	0.57	0.04	NA	NA	0.81	0.04	0.53	0.04	0.44	0.05	NA	NA	0.63	0.06
2017	0.77	0.06	0.80	0.06	NA	NA	NA	NA	0.82	0.14	0.63	0.10	NA	NA	NA	NA
2018	0.83	0.04	0.54	0.04	NA	NA	0.76	0.04	0.60	0.06	0.42	0.06	NA	NA	0.59	0.07
2019	0.67	0.04	0.69	0.03	0.63	0.03	0.79	0.04	0.45	0.10	0.50	0.08	0.53	0.10	0.56	0.11
2020	0.66	0.06	0.56	0.04	NA	NA	0.82	0.03	0.22	0.05	0.37	0.08	NA	NA	0.60	0.04
2021	0.83	0.05	NA	NA	NA	NA	0.80	0.03	1.39*	0.78	NA	NA	NA	NA	0.75*	0.25
Average	**0.75**		**0.63**		**0.63**		**0.77**		**0.55**		**0.47**		**0.53**		**0.59**	

*Value not used in the average due to high standard error.

Table 4. Sub yearling survival (generated via DART CJS) for hatchery and natural-origin summer Chinook released from various locations to Rocky Reach and McNary dams, 2015–2021.

Note: The Chief Joseph Hatchery Segregated Program is indicated by CJH segr. The majority of natural-origin summer Chinook were tagged and released from a beach seine survey at the confluence of the Okanagan and Columbia Rivers.

Summer Chinook Subyearling Release Group																
	Survival to Rocky Reach Dam								**Survival to McNary Dam**							
Release Year	**CJH segr.**		**Omak Pond**		**Wells Hatchery**		**Natural-origin**		**CJH segr.**		**Omak Pond**		**Wells Hatchery**		**Natural-origin**	
	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr
2015	0.28	0.08	0.37	0.09	0.43	0.06	0.26	0.06	0.20	0.20	0.23	0.15	0.77	0.76	NA	NA
2016	0.44	0.08	0.35	0.05	0.51	0.05	0.24	0.03	0.14	0.05	0.14	0.06	0.25	0.05	NA	NA
2017	0.65	0.05	0.70	0.05	0.48	0.06	0.46	0.02	0.34	0.06	0.48	0.07	0.22	0.05	0.18	0.02
2018	0.65	0.06	NA	NA	0.79	0.07	0.44	0.04	0.53	0.09	NA	NA	0.53	0.11	0.12	0.03
2019	NA	NA	NA	NA	0.59	0.03	0.36	0.02	NA	NA	NA	NA	0.29	0.20	0.18	0.05
2020	0.49	0.08	0.45	0.05	0.59	0.05	0.43	0.03	0.23	0.08	0.27	0.08	0.39	0.12	0.37	0.15
2021	0.39	0.12	0.43	0.08	0.62	0.07	0.42	0.06	NA	NA	0.32*	0.31	0.98*	0.97	NA	NA
Average	**0.48**		**0.46**		**0.57**		**0.37**		**0.29**		**0.28**		**0.41**		**0.21**	

3.3.2 Canadian Okanagan studies

The ONA has been raising Chinook eggs at the kł cp̓əlk̓ stim̓ Hatchery in Penticton since 2016. Since 2019, yearling Chinook have been released with PIT tags with targeted release sizes of 20,000–25,000 per year. Survival estimates from these releases are presented in Table 5. These estimates were obtained from Columbia River DART. DART does not constrain survival estimates to be less than 1 and it is possible to estimate values greater than 1, particularly when detection probability is low, as observed in a few years. These values are typically associated with high standard errors.

Not all fish released from kł cp̓əlk̓ stim̓ Hatchery actively migrate during the year of release. On average, 8% of yearlings and 56% of subyearlings were detected at least once the following year. Therefore, the survival estimates reported in Table 5 are not specific to the year of interest, but rather for the entire release group. Furthermore, there is also some evidence that some of the kł cp̓əlk̓ stim̓ Hatchery releases residualize in lakes and never migrate out to sea. There is no way for the Columbia River DART to separate residualization from death or lack of detection. Therefore, the survival estimates reported in Table 5 are likely biased low if the intended inference is for survival during the outmigration year of interest.

Table 5. Survival of yearling Chinook released from kł cp̓əlk̓ stim̓ Hatchery to the PIT array in the Okanagan (OKC), Zosel Dam (ZSL) and Rocky Reach (RRE).

		Release - OKC		OKC - ZSL		ZSL - RRE		Release - RRE	
Year	Release Month	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
2019	April	0.58	0.20	0.48	0.32	0.15	0.10	0.04	0.02
2020	November	1.09	0.09	0.17	0.04	1.32	0.45	0.24	0.07
2021	April	0.79	0.10	0.39	0.07	0.53	0.08	0.17	0.02
2022	January	0.69	0.03	4.70	4.67	0.06	0.06	0.18	0.33
Average		0.79	0.11	1.44	1.27	0.51	0.17	0.16	0.11

3.3.3 Comparison of survival estimates

Standardized survival estimates (Table 6 and Table 7) were calculated to compare survival estimates among reaches of different lengths. Survival per 10 kilometers was calculated by transforming the survival estimates in Table 4 and Table 5 by $Survival^{1/(Length/10)}$, where *Length* is the length of the reach (Table 6 and Table 7).

Comparing standardized release to Rocky Reach survival estimates in Table 6 and Table 7 indicates that Okanagan summer yearling Chinook released from kł cp̓əlk̓ stim̓ Hatchery generally have lower survival compared to all other U.S. Okanagan yearling release groups after accounting for distance. Comparing reach-specific survival estimates in Table 7 indicates that the largest source of mortality for Okanagan summer Chinook occurs between the Okanagan array and Zosel Dam after accounting for distance. This finding supports hypotheses about survival bottlenecks, such as those that might occur in Osoyoos Lake due to predation, low oxygen, or high temperature, but it may also identify the reach where the fish with the residual life history remain.

Table 6. Standardized survival (per 10 km) for yearling hatchery summer Chinook released from various locations to Rocky Reach and McNary dams, 2015–2021.
Note: The Chief Joseph Hatchery Segregated Program is indicated by CJH segr. and the Similkameen Program is indicated by Similk.

	Release To Rocky Reach				Release To McNary			
Year	**CJH Seg**	**Omak**	**Similk**	**Carlton**	**CJH Seg**	**Omak**	**Similk**	**Carlton**
2015	0.97			0.97	0.99			0.99
2016	0.98	0.96		0.98	0.98	0.98		0.99
2017	0.98	0.98			1.00	0.99		
2018	0.98	0.96		0.98	0.99	0.98		0.99
2019	0.96	0.98	0.98	0.98	0.98	0.98	0.98	0.99
2020	0.96	0.96		0.99	0.96	0.98		0.99
2021	0.98			0.98	1.01*			0.99*

* Value associate with high standard error

Table 7. Standardized survival (per 10 km) for yearling hatchery Chinook released from kł cp̓əlk̓ stim̓ Hatchery to the array in the Okanagan (OKC), Zosel Dam (ZSL) and Rocky Reach (RRE).

Year	Release to OKC	OKC - ZSL	ZSL - RRE	Release to RRE
2019	0.64	0.75	0.92	0.89
2020	1.07*	0.49	1.01*	0.95
2021	0.89	0.69	0.97	0.94
2022	0.88	1.86*	0.88	0.94

* Value associated with high standard error

3.3.4 Comparative survival study

The Fish Passage Center's Comparative Survival Study (CSS) provides Smolt-to-Adult Return (SARs) estimates for salmon populations throughout the Columbia River Basin. In recent years, the CSS began reporting SARs for natural-origin summer Chinook tagged and released from the beach seine survey at the confluence of the Okanagan and Columbia Rivers. These estimates are provided in Table 8 and are taken from the most recent CSS report (Comparative Survival Study Oversight Committee and Fish Passage Center 2022). Overall, mean SARs have been declining since migration year 2013 and were generally less than 1% in all but one year.

Table 8. Smolt-to-adult return estimates for Upper Columbia natural-origin summer Chinook tagged and released from the beach seine survey at the confluence of the Okanagan and Columbia Rivers (Okanagan River or Columbia Mainstem above Wells Dam)[1] from 2011 to 2018, taken from the most recent CSS report (Comparative Survival Study Oversight Committee and Fish Passage Center 2022) from smolts migrating past Rocky Reach (RRE) to adults returning past Wells (WEA) Dam.

Migration Year	Smolts Arriving RRE[2]	RRE-to-WEA (without jacks)			RRE-to-WEA (with jacks)		
		% SAR Estimated	Non-parametric CI		% SAR Estimated	Non-parametric CI	
			90% LL	90% UL		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	1.2	0.97	1.42
2014	3,147	0.06	0.00	0.14	0.06	0.00	0.14
2015[3]	2,065	0.00	0.00	0.14	0.00	0.00	0.14
2016[3]	3,485	0.00	0.00	0.09	0.00	0.00	0.09
2017	10,777	0.29	0.2	0.38	0.3	0.21	0.39
2018[4]	10,861	0.11	0.06	0.17	0.11	0.06	0.17
Arithmetic mean (Including Zeros)		0.36			0.39		
Geometric mean (Excluding zeros)		0.31			0.33		

[1] 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.
[2] 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.
[3] Due to zero adult returns, 90% confidence interval are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).
[4] Incomplete, 3-salt returns through September 25, 2021.

3.3.5 Predation

There are several known causes of juvenile salmon mortality in the mainstem Columbia River that may be of concern to Okanagan summer Chinook. Predation by native and non-native fishes such as northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass, walleye (*Sander vitreus*) and channel catfish (*Ictalurus punctatis*) is a well-known and extensively studied issue in the Hanford Reach just below Priest Rapids Dam. In one study, McMichael and James (2017) report that smallmouth bass, walleye and northern pikeminnow consumed 3.2 million, 8.1 million and 12.6 million salmonids respectively between April 1 and August 31, 2016 in this area. Predation rates can be high on juvenile Chinook salmon, particularly on subyearling outmigrants, in the mainstem of the Columbia River. Studies of juvenile Upriver Bright fall Chinook report a range of estimated survivals, in part due to differences in study design which makes it difficult to directly compare the estimates; one study found the survival of natural-origin subyearlings to be about 35% from Hanford Reach to McNary Dam (Harnish et al. 2014; McMichael 2018), while the ongoing PIT studies for Columbia summer Chinook stocks (Table 4) suggest an average survival of about 60% from Rocky Reach Dam to McNary Dam. Most of the mortality in this reach is due to predation. Programs to remove predator species such as the Northern Pikeminnow Management Program have helped to reduce predator populations and need to be maintained. It is likely that predation by these species is also a major mortality factor in the Canadian lakes and the U.S. portion of the Okanagan River, as well as the Columbia River upstream of the Hanford Reach.

Avian species are another well-known source of predators of juvenile salmonids. For instance, Roby et al. (2003) estimated that Caspian terns (*Hydroprogne caspia*) nesting on Rice Island in the Columbia River estuary consumed between 8.1–12.4 million salmon smolts annually. Recent work (Payton et al. in press) on a subyearling Chinook population similar to Okanagan Chinook, Upriver Brights, has indicated that avian predators, especially American White Pelican (*Pelecanus erythrorhynchos*) populations, account for as much as 29.1% of the total mortality on smolts. Avian predation studies on juvenile salmonids in the Columbia River Basin need to continue and managers should consider population control techniques if the avian predator species can sustain removal and are not subject to U.S. and Canadian treaty provisions regarding protection of migratory birds.

3.3.6 Smolt survival insights

Juvenile salmon smolt mortality in the mainstem Columbia River is well researched and is understood to be predominantly due to the immediate and delayed effect of passage through hydroelectric dams. Some mortality is directly attributed to the dams, such as gas bubble disease (Elston et al. 1997), whereas others are indirectly attributed, such as the predation in reservoirs. These effects depend on a variety of factors including flow, spill percentage, water transit time and cumulative bypass exposure and many more. Federal and PUD operated dams are required to meet dam- and species-specific performance standards[2]. It is important that these standards are not lowered and continue to be met for the benefit of Okanagan summer Chinook.

3.4 Marine

An exploitation rate analysis (ERA) was conducted for yearling summer Chinook CWTs released into the Okanagan and Similkameen Rivers. An ERA is a cohort analysis technique developed by the CTC and is annually conducted for a number of different indicator stocks. Cohort analysis simply reconstructs the production of a CWT group 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.

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[2]At Wells, Rocky Reach and Rock Island dams, the survival standard for juvenile sockeye, steelhead and yearling Chinook is 93% (through dam and pool). At the Priest Rapids Projects (this includes Wanapum and Priest Rapids dams and both pools), the survival standard is 86.49%, which is a combined survival of 93% for each dam and pool. If the PUDs are not able to estimate survival in the pools, they are allowed to meet a standard of 95% at the dams themselves (i.e., forebay to tailrace).

Once the cohort reconstruction is complete, several different metrics that form the basis of the ERA can be calculated. This analysis primarily focuses on metrics related to the marine environment including: release to age-3 survival, brood-year exploitation rates, maturation rates and distribution of mortality by calendar year. The Annual Exploitation Rate Analysis Report produced by the CTC (e.g., CTC 2022) includes additional summaries along with methodological descriptions of these metrics.

3.4.1 CWT data quality

Yearling CWT releases of summer Chinook at Similkameen Pond began with brood year 1989. 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. There were no releases in 1998 for unknown reasons. Finally, there were disease issues associated with the 2001 brood (Charlie Snow, Washington Department of Fish and Wildlife [WDFW], personal communication) that resulted in a small release size of approximately 26,000 individuals. Given the small size and potential unrepresentativeness of the run at large due to residual disease effects, tag codes from this brood were also excluded. Tag codes within a brood will get pooled for the ERA. The total release sizes and recoveries for the remainder of the broods (Appendix E1) are supportive of a robust ERA.

3.4.2 Inter-dam loss estimates

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 adult in-river 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 broodstock collection. Theoretically, these estimates should be less than one, but estimates are quite often greater than one due to errors in counts at dams and other sources of uncertainty. Each estimate in these calculations was constrained to one, and the estimate between multiple dams was calculated as the product of each reach-specific IDL.

Inter-dam survival estimates from Bonneville to Rock Island and from Bonneville to Wells are provided in Figure 7. Reach-specific inter-dam survival estimates are provided in Table 9. The Bonneville to McNary estimate excluded fishery catches occurring in this reach and was based on McNary dam counts from 24 June to 8 August (adjusted to remove Snake spring/summer returns). The McNary to Priest Rapids estimate excluded fish counted at Snake River dams, Hanford reach sport catches, and Wanapum tribal catches. The Rock Island to Rocky Reach estimate excluded Wenatchee River escapement estimates and Eastbank Hatchery broodstock collection. The Rocky Reach to Wells survival excluded Entiat and Chelan escapements and Wells Hatchery broodstock collection.

Inter-dam loss estimates should ideally be calculated to wherever harvest ends, and escapement begins. However, these estimates are typically calculated to a convenient upstream reference location (e.g., Wells Dam). To conduct the ERA in the current algorithm used by the CTC, only escapement CWT recoveries are expanded by the IDL estimate. Therefore, any harvest that occurs upstream of where the IDL is calculated needs to get categorized as escapement so that these recoveries can also get expanded by the IDL estimate. This was done prior to the backwards cohort reconstruction. When reporting the distribution of mortality by calendar year, adjustments are made so that the recategorized harvest recoveries are appropriately represented.

Table 9. Inter-dam loss estimates (IDL) for Okanagan summer Chinook (SMK) by Columbia River Reach by run year. Dam acronyms are Bonneville (BON), McNary (MCN), Priest Rapids (PRD), Rock Island (RI), Rocky Reach (RRE) and Wells (WE).

Year	BON - MCN	MCN - PRD	PRD - RI	RI - RRE	RRE - WE	IDL
1989	0.75	1.00	0.89	0.77	1.00	0.51
1990	0.82	1.00	0.86	0.88	1.00	0.62
1991	0.81	1.00	0.69	1.00	1.00	0.55
1992	0.80	1.00	0.90	1.00	0.96	0.70
1993	0.92	1.00	0.79	1.00	0.98	0.71
1994	0.76	1.00	0.83	1.00	1.00	0.63
1995	0.85	1.00	0.87	1.00	1.00	0.74
1996	0.91	1.00	0.86	1.00	0.66	0.51
1997	0.81	1.00	0.75	1.00	0.62	0.38
1998	0.72	1.00	0.84	1.00	0.73	0.44
1999	0.77	1.00	0.99	0.75	0.88	0.51
2000	0.69	1.00	1.00	0.99	0.53	0.36
2001	0.88	1.00	0.94	1.00	0.91	0.75
2002	0.90	1.00	0.90	0.99	0.88	0.71
2003	0.82	1.00	0.98	0.90	0.77	0.55
2004	0.77	1.00	0.93	0.80	0.79	0.45
2005	0.88	1.00	0.88	0.93	0.79	0.57
2006	0.87	1.00	1.00	0.92	0.67	0.54
2007	0.78	1.00	0.92	0.90	0.68	0.43
2008	0.80	1.00	0.97	0.90	0.81	0.57
2009	0.84	1.00	0.90	0.97	0.81	0.59
2010	0.90	1.00	0.96	0.85	0.90	0.66
2011	1.00	1.00	0.87	1.00	0.86	0.75
2012	0.96	1.00	1.00	1.00	0.98	0.94
2013	0.93	1.00	0.96	0.99	0.91	0.82
2014	1.00	1.00	0.99	0.87	0.90	0.78
2015	0.83	1.00	1.00	0.91	0.84	0.64
2016	0.87	1.00	0.99	0.81	0.81	0.56
2017	0.82	1.00	1.00	0.89	0.78	0.56

Year	BON - MCN	MCN - PRD	PRD - RI	RI - RRE	RRE - WE	IDL
2018	0.84	1.00	0.97	0.95	0.77	0.59
2019	0.78	1.00	1.00	1.00	0.70	0.55
2020	0.90	1.00	1.00	0.97	0.83	0.72

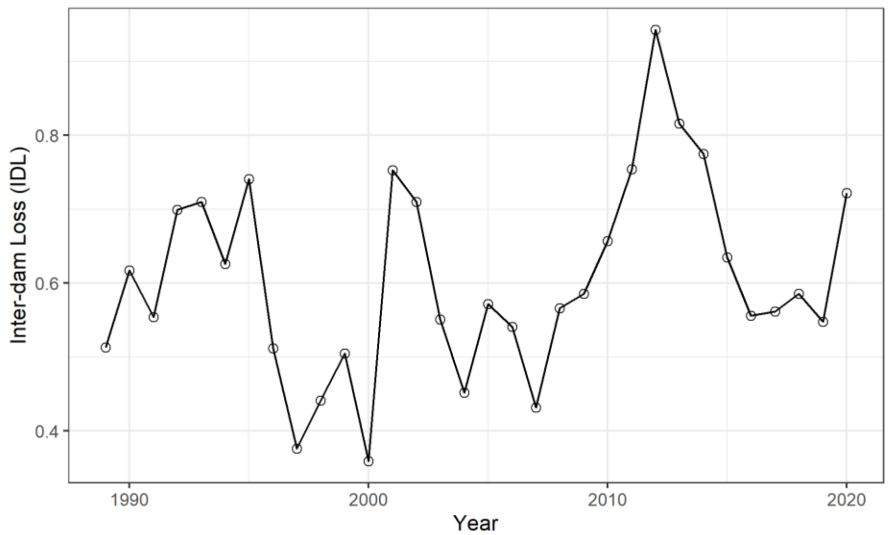

Figure 7. Inter-dam loss estimates (IDL) for Okanagan summer Chinook (SMK).

3.4.3 ERA results

3.4.3.1 Release to age-3 survival

Release to age 3 (prior to "over winter" natural mortality) survival estimates are provided in Figure 8. These estimates include in-river migration, estuary and ocean-entry related mortality during the first year at sea. These estimates are based on CWT recoveries up until calendar year 2020 and so not all ages from cohorts 2015–2017 are completed. Accordingly, the survival estimates from cohorts 2015–2017 will change, particularly the most recent estimate for 2017. The preliminary survival estimate for the 2017 cohort is very low, but this is affected by not including recovery information from the remaining ages in this cohort, thus the survival rate will increase as the cohort matures and completes. The CWT-based survival rates were examined relative to the mean rank of "NOAA Ocean Indicators" that were aligned to the same ocean entry year for the Chinook smolts (NOAA 2022), however there was very little correlation (R^2 = 0.07) and it was not a useful indicator of yearling smolt survival for Okanagan summer Chinook (F = 1.018, *P* =0.33; Figure 9).

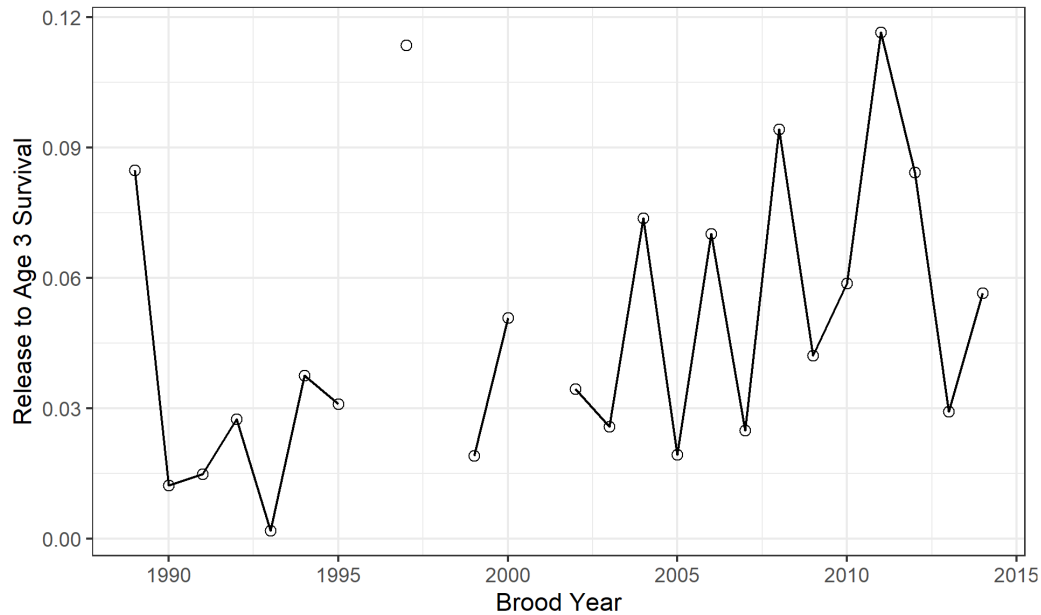

Figure 8. Release to age 3 survival estimates for yearling Okanagan summer Chinook (SMK) smolts by brood year (1989–2014).
Note: See Appendix E2 for the raw data used to create this figure.

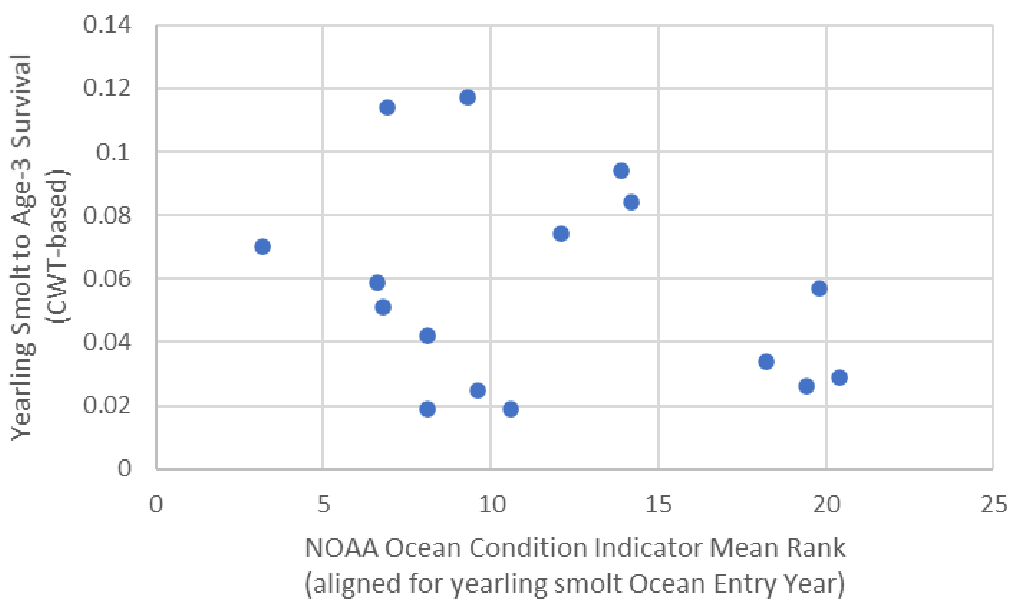

Figure 9. National Oceanic and Atmospheric Administration (NOAA) ocean condition indicator mean rank (aligned for yearling smolt Ocean Entry Year) and the survival rate for yearling smolts to age 3 based on coded-wire tag (CWT) data analysis of Okanagan summer Chinook.

3.4.3.2 Maturation rates

Maturation rates by brood year and age are shown in Figure 10. These estimates show an increasing trend in age 4 and 5 maturation rates, indicating that summer Chinook are now returning at younger ages than historically observed, which is similar to the widespread pattern reported for many Chinook stocks from Oregon to Southeast Alaska (Freshwater et al. 2021).

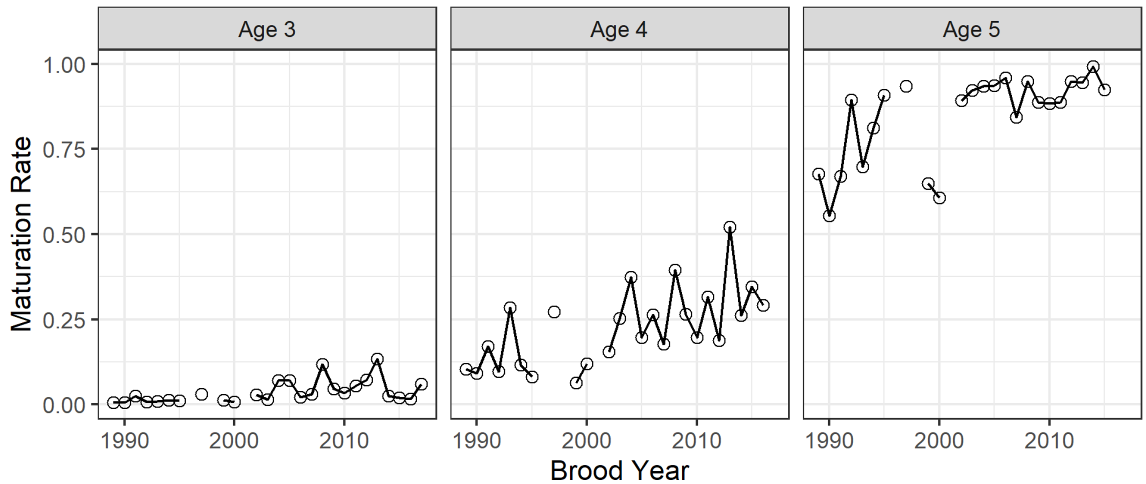

Figure 10. Maturation rates for Okanagan summer Chinook (SMK) by brood year and age.
Note: The age 6 maturation rate is assumed to be 1.
Note: See Appendix E3 for the data used to create this figure.

3.4.3.3 Brood year exploitation rates

Brood year exploitation rates summed across all ocean fisheries are shown in Figure 11. The total estimate is separated into landed catch and incidental mortality components. Only estimates for complete cohorts are shown since an estimate for an incomplete cohort would not show the full extent of ocean exploitation across the cohort. Since brood year 2007, ocean exploitation rates have been steadily declining. This pattern may partially be explained by fishery regime changes coinciding with the 2009 PST Agreement (PST 2010). The total brood year exploitation rates among all ocean and freshwater fisheries were not summarized due to issues representing the impacts of mark selective fisheries on unmarked Chinook, and these exploitation rates will need to be generated when methods have been adopted by the PSC (e.g., by the Calendar Year Exploitation Rate (CYER) Work Group and the CTC).

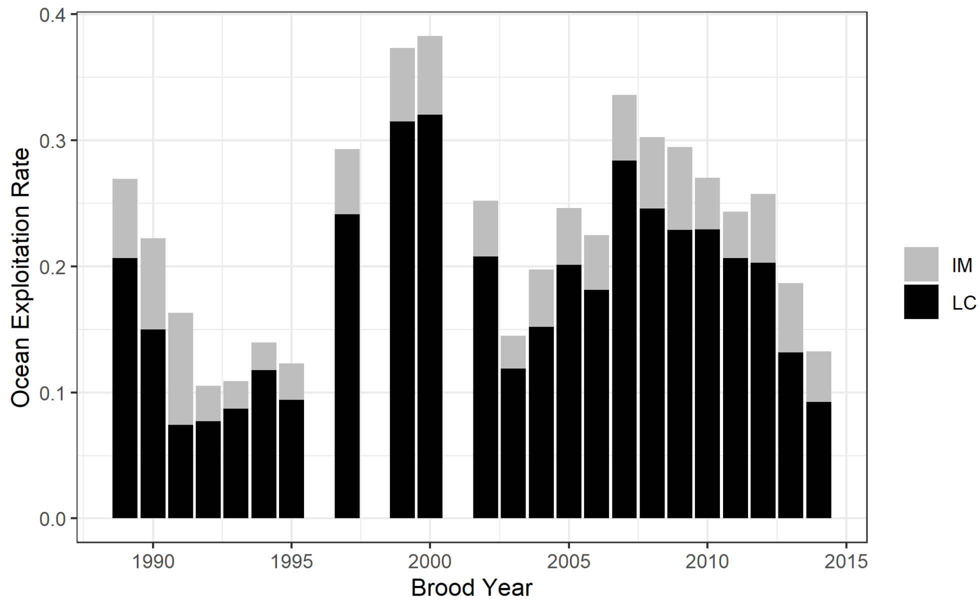

Figure 11. Ocean exploitation rates for Okanagan summer Chinook (SMK) by landed catch (LC), incidental mortality (IM) and total mortality (LC + IM) estimates by brood year.
Note: See Appendix E4 for the raw data used to create this figure.

3.4.3.4 Mortality distribution

The mortality distribution table is shown in Table 10. This table shows the percentage of adult equivalent (AEQ) total mortality in specific fisheries and escapement by calendar year. These percentages are the result of readjusting the raw percentages produced by the CTC mortality distribution program to reflect the recategorized harvest recoveries upstream of Wells Dam described in the inter-dam loss section. A condensed version of this distribution table is shown in Figure 12. Average percentages by PST agreements are shown at the bottom of the table. This table and figure identify a northerly ocean distribution as indicated by the percentages of mortality in both Southeast Alaska (SEAK) and Northern British Columbia (NBC) aggregate abundance-based management (AABM) fisheries, which have recently declined. The percentage of mortality in U.S. individual stock-based management (ISBM) fisheries has been decreasing since 2014 and has resulted in an increase in the percent of fish that successfully arrive at escapement areas during the same time period. The percentage of mortality in Canadian AABM fisheries is very low (< 2.5%) in 2019 and 2020, which reflects fishery management changes in Canada directed at protecting a number of Chinook salmon stocks of concern.

Table 10. Mortality distribution for Okanagan summer Chinook (SMK) 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		WAC	Puget Sd		Columbia			
Year	CWT	Ages	T	N	S	T	S	T	S	T	N	S	T	N	S	T	S	T	S	N	N	S	N	S	Stray	Esc.
1992	271	3	Failed Criteria			-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
1993	1,257	3,4	13.9	0.4	1.8	4.5	0.3	14.6	0.9	1.0	2.0	0.0	0.0	0.4	0.6	2.1	2.6	0.2	0.0	0.0	0.0	0.9	3.8	0.8	0.1	49.1
1994	3,737	3,4,5	10.3	3.8	1.0	4.5	0.6	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	0.0	1.4	0.2	0.1	74.1
1995	2,425	3,4,5,6	9.2	0.2	2.9	1.7	2.4	3.5	0.4	0.3	0.9	0.0	0.0	0.4	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.3	0.2	0.2	77.0
1996	2,022	3,4,5,6	4.8	0.1	0.6	0.5	0.2	1.3	0.1	0.0	0.2	0.1	0.0	0.0	0.3	0.4	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.4	7.1	83.1
1997	4,298	3,4,5,6	4.0	0.0	1.0	0.0	0.5	0.5	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	92.9
1998	1,134	3,4,5,6	16.8	0.4	0.0	3.0	0.0	0.0	0.3	0.0	0.0	0.8	0.0	0.1	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0	1.1	0.3	0.0	76.5
1999	2,679	4,5,6	9.2	0.0	2.3	0.3	1.4	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.8	0.1	1.1	0.0	0.0	0.0	0.0	0.2	0.3	0.6	83.3
2000	6,843	3,5,6	8.0	0.2	0.9	1.8	1.2	1.2	0.2	0.0	0.3	0.1	0.0	0.0	0.0	0.4	0.3	0.5	0.0	0.0	0.0	0.0	0.1	1.5	0.5	82.5
2001	9,051	4,6	8.6	0.2	1.1	1.6	1.3	4.0	0.7	0.0	0.0	0.3	0.0	0.0	0.1	1.9	0.8	3.5	0.4	0.0	0.0	0.0	0.2	0.3	0.2	74.6
2002	13,329	3,5	10.7	0.0	0.7	10.3	1.7	5.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	1.1	0.7	0.5	0.1	0.0	0.0	0.0	0.6	1.9	0.1	66.4
2003	1,530	3,4,6	16.4	0.1	3.2	8.7	3.4	9.4	0.5	0.0	0.0	1.6	0.0	0.0	0.1	3.7	1.9	3.1	0.6	0.0	0.1	0.5	2.7	7.8	0.8	35.5
2004	4,306	4,5	11.9	0.8	1.3	5.5	2.3	7.3	0.7	0.0	0.0	0.4	0.0	0.0	0.1	2.7	0.6	2.8	0.6	0.0	0.0	0.2	6.6	15.5	0.3	40.4
2005	5,997	3,5,6	12.7	0.1	1.1	9.0	4.5	5.9	0.2	0.0	0.1	0.0	0.0	0.0	0.2	1.3	0.6	2.1	0.2	0.0	0.0	0.0	7.5	7.8	1.0	45.8
2006	2,685	3,4,6	8.3	2.1	0.9	5.2	3.3	4.6	0.7	0.0	0.0	0.0	0.0	0.0	0.9	2.4	0.2	0.5	0.1	0.0	0.0	0.1	14.2	9.7	0.4	46.2
2007	5,737	3,4,5	6.8	0.5	1.3	1.3	2.2	3.1	0.5	0.0	0.7	0.3	0.0	0.0	0.2	0.7	0.5	0.5	0.2	0.0	0.0	0.1	4.0	23.0	0.1	53.9
2008	10,617	3,4,5,6	10.1	0.1	0.8	1.2	2.2	1.6	1.1	0.0	0.0	0.1	0.0	0.0	0.2	0.9	0.4	0.0	0.0	0.0	0.0	0.0	15.8	11.8	0.4	53.3
2009	8,477	3,4,5,6	7.5	0.1	0.7	2.9	2.5	3.0	1.6	0.0	0.0	0.2	0.0	0.0	0.5	0.8	0.3	0.0	0.0	0.0	0.0	0.2	14.6	9.0	0.3	55.6
2010	7,383	3,4,5,6	9.8	0.3	1.6	3.3	1.4	4.8	0.7	0.0	0.0	1.2	0.0	0.0	0.2	2.8	1.1	0.9	0.0	0.0	0.0	0.1	16.5	9.1	0.5	45.7
2011	12,378	3,4,5,6	7.1	0.1	0.8	2.6	1.2	1.9	1.3	0.0	0.0	0.4	0.0	0.0	0.2	0.6	1.1	1.1	0.2	0.0	0.0	0.1	17.3	17.0	0.4	46.6
2012	9,795	3,4,5,6	12.9	0.5	0.7	3.0	1.2	4.7	2.5	0.0	0.0	0.6	0.0	0.0	0.9	4.5	3.2	3.4	1.0	0.0	0.0	0.2	6.8	26.5	0.3	27.1
2013	8,100	3,4,5,6	6.7	0.3	0.6	3.6	2.4	2.6	1.2	0.0	0.0	0.1	0.0	0.0	0.4	3.2	1.2	2.5	0.3	0.0	0.0	0.3	22.7	17.4	0.0	34.4
2014	10,683	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	0.0	35.5	9.4	0.1	28.6
2015	18,544	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	0.0	3.4	2.4	1.3	0.1	0.0	0.0	0.0	31.2	8.1	0.2	40.1
2016	16,540	3,4,5,6	14.0	0.4	1.2	3.0	1.9	4.0	0.9	0.0	0.0	0.4	0.0	0.0	0.3	1.3	0.6	2.3	0.0	0.0	0.0	0.0	16.4	8.9	0.0	44.3
2017	7,222	3,4,5,6	6.1	0.2	1.4	2.6	3.3	3.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.5	0.8	0.1	0.0	0.0	0.1	16.9	12.5	0.2	48.0
2018	5,149	3,4,5,6	7.0	0.1	1.0	2.5	1.0	2.8	0.7	0.0	0.0	0.6	0.0	0.0	0.3	4.8	0.7	0.5	0.3	0.0	0.0	0.1	23.5	9.9	0.1	44.1

	Est		AABM Fishery							ISBM Fishery																Escapement	
Catch	# of		SEAK			NBC		WCVI		NBC & CBC			Southern BC			N Falcon		S Falcon		WAC	Puget Sd		Columbia				
Year	CWT	Ages	T	N	S	T	S	T	S	T	N	S	T	N	S	T	S	T	S	N	N	S	N	S		Stray	Esc.
2019	8,268	3,4,5,6	3.9	0.4	0.2	0.8	0.3	0.2	0.3	0.0	0.0	0.6	0.0	0.0	0.1	1.0	1.1	0.4	0.1	0.0	0.0	0.0	10.9	22.3		0.4	56.9
2020	6,840	3,4,5,6	6.8	0.2	0.2	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.6	0.4	0.1	0.0	0.0	0.1	10.1	11.2		0.2	69.0
85-95	1,923		11.2	1.5	1.9	3.5	1.1	7.1	0.5	0.5	1.0	0.0	0.0	0.3	0.2	0.7	0.9	0.1	0.1	0.0	0.0	0.3	1.8	0.4		0.1	66.7
96-98	2,485		8.5	0.2	0.5	1.2	0.2	0.6	0.1	0.0	0.1	0.3	0.0	0.1	0.1	0.1	0.1	0.5	0.0	0.0	0.0	0.0	0.4	0.2		2.4	84.2
99-08	6,277		10.3	0.4	1.4	4.5	2.3	4.2	0.5	0.0	0.1	0.3	0.0	0.0	0.2	1.6	0.6	1.5	0.2	0.0	0.0	0.1	5.2	8.0		0.5	58.2
09-18	10,427		9.0	0.2	0.9	2.6	1.6	3.3	1.0	0.0	0.0	0.4	0.0	0.0	0.3	2.7	1.4	1.5	0.2	0.0	0.0	0.1	20.2	12.8		0.2	41.4
19-28	7,554		5.4	0.3	0.2	0.6	0.2	0.1	0.1	0.0	0.0	0.3	0.0	0.0	0.1	0.7	0.9	0.4	0.1	0.0	0.0	0.0	10.5	16.7		0.3	63.0

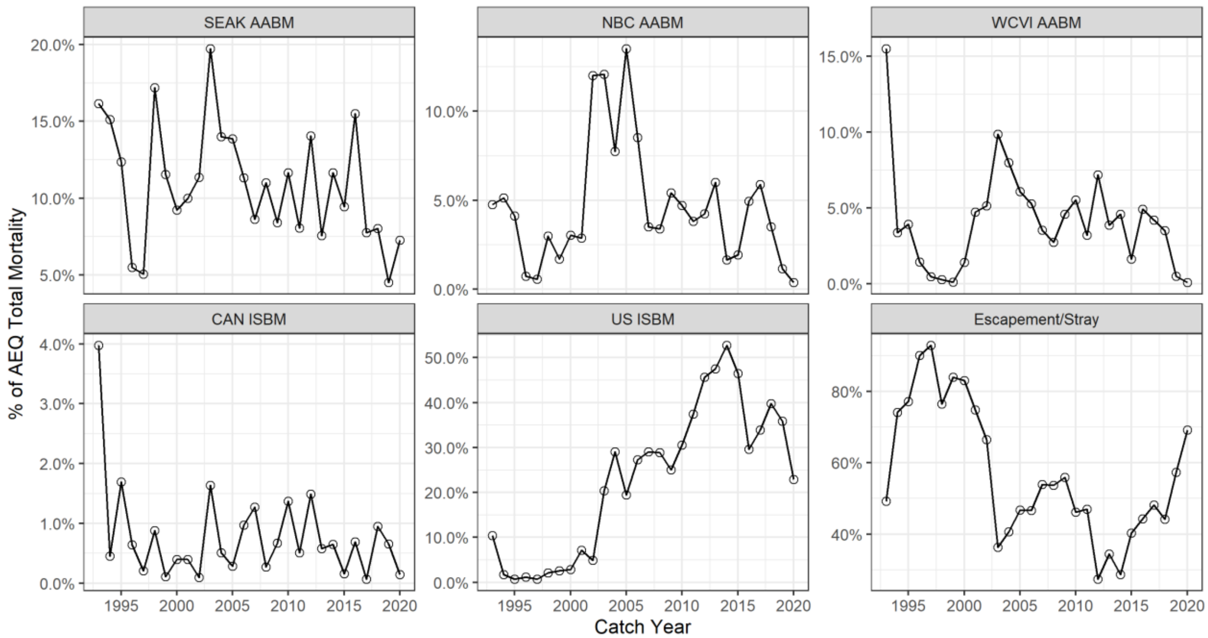

Figure 12. Condensed plot of the mortality distribution for Okanagan summer Chinook (SMK) in Table 10 for catch years 1993 to 2020.

A geographic representation of the ocean distribution of Okanagan summer Chinook is presented in Figure 13. This plot shows the sum of the estimated number of CWT recoveries in fisheries across all years by unique latitude and longitude to the second decimal point. It is important to note that some Regional Mark Information System (RMIS) recovery locations did not have geographic coordinates submitted with their records and so some recoveries are not illustrated. In total, 742 estimated recoveries are not shown due to missing geographic coordinates. This map shows many of the same patterns in the mortality distribution tables and plots. Okanagan summer Chinook have a northerly ocean distribution as indicated by the high number of recoveries in both SEAK and NBC AABM fisheries. The largest number of recoveries occurs in the Columbia River in both in-river fisheries and escapement.

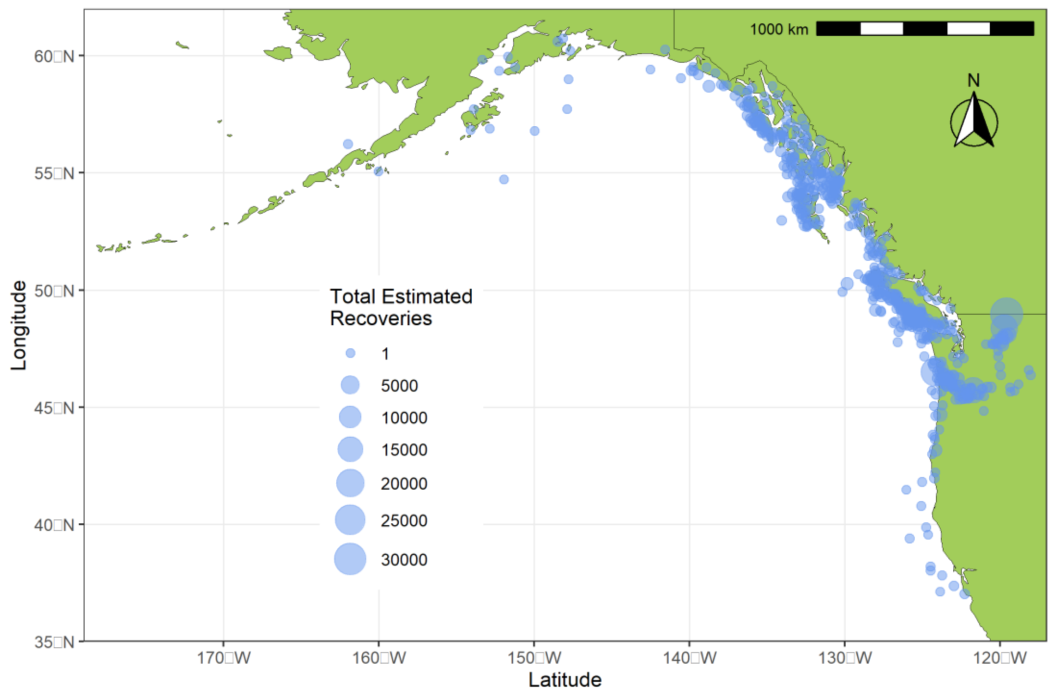

Figure 13. The ocean distribution as indicated by cumulative coded-wire tag (CWT) recoveries for Okanagan summer Chinook (SMK) across all years since 1992.

3.4.4 Fisheries Regulation Assessment Model (FRAM)

The Fishery Regulation Assessment Model (FRAM) is an accounting tool to estimate the impacts of proposed fisheries on Chinook for the southern U.S. domestic fishery planning process. Recent work was done to FRAM to improve estimates of Columbia summer Chinook impacts in ocean fisheries. Genetic stock identification (GSI) analysis indicated that the recently updated FRAM base period resulted in significant over-estimates of impacts in marine fisheries, with the magnitude of overestimation in the Central Oregon troll fishery being particularly pronounced. This issue has been addressed starting in 2019. A summary of that work is available at the Pacific Fishery Management Council (PFMC) website (Hagen-Breaux et al. 2019).

3.4.5 Fishery sampling rates

Fishery sampling rates provide an indication of the quality of the CWT data, and subsequently derived statistics, and a general guideline of a 20% CWT sampling rate is recommended by the PSC (PSC Coded Wire Tag Work Group 2008). Since the uncertainty in the CWT-based statistics depends in part on the quantity and quality of the CWT recoveries from fisheries, both the number of observed CWTs sampled from fisheries and the fishery sampling rates for Okanagan Chinook were examined over the most recent five years (Table 11). From 2016–2020, the Columbia River net and sport fisheries exceeded the 20% fishery CWT sampling rate guideline in only one of five years, and since these fisheries accounted for the largest components of the fishery CWT estimated recoveries, 36% and 26% respectively, these are the most important fisheries to focus on in an effort to improve the overall quality of CWT data for Okanagan Chinook. Four other fisheries had at least one year with sampling rates below 20%, but these fisheries represented a very small amount (<4%) of the estimated CWT recoveries for this stock, and all other fisheries had CWT sampling rates that met the PSC guideline.

Table 11. Summary of the number of observed, estimated, and weighted average sample rates for coded-wire tag (CWT) recoveries of the Okanagan summer Chinook (SMK) stock by year (2016–2020) and fishery, as indicated by geographic area and fishery description.
Note: Under-sampled fisheries were based on weighted average sampling rates below the 20% sampling rate guideline and the relative catch of the stock over all years was based on the estimated CWT recoveries reported in the Regional Mark Information System (RMIS).

Geographic Area	Fishery Description	Observed CWTs					Estimated CWT Recoveries					Weighted Average Sample Rates					Percentage of Years Under-sampled	Relative Catch of Stock
		2016	2017	2018	2019	2020	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020		
SEAK	Troll	474	169	102	88	114	1192	346	244	251	369	40%	49%	42%	35%	31%	0%	13%
	Sport	57	41	16	5	8	176	76	42	12	14	32%	54%	38%	43%	58%	0%	2%
	Net	29	7	2	9	5	59	13	2	14	12	49%	53%	100%	65%	42%	0%	1%
BC North & Central Coast	Troll	104	47	38	18	8	457	165	114	53	22	23%	28%	33%	34%	36%	0%	4%
	Sport	82	26	24	13	1	345	177	81	62	3	24%	**15%**	30%	21%	32%	20%	4%
WCVI	Troll	191	67	52	8	2	611	236	150	19	4	31%	28%	35%	43%	48%	0%	5%
	Sport	21	5	7	6	2	164	21	36	32	2	**13%**	24%	**19%**	**19%**	100%	60%	1%
	First Nation Mixed	10	6	3	0	0	21	17	5	0	0	47%	34%	61%	-	-	0%	0%
Strait of Georgia	Sport	1	1	2	0	1	9	2	12	0	6	**11%**	41%	**17%**	-	**16%**	75%	0%
Puget Sound	Sport	4	1	3	0	1	10	5	12	0	5	41%	22%	25%	-	**20%**	25%	0%
	Net	0	0	0	1	0	0	0	0	1	0	-	-	-	80%	-	0%	0%
WA/OR/CA Coast	Troll	248	83	153	55	28	561	185	259	99	50	44%	45%	59%	55%	56%	0%	6%
	Sport	28	37	23	27	17	78	72	44	66	45	36%	51%	52%	41%	38%	0%	2%
	Net	3	1	2	2	0	12	2	5	6	0	24%	50%	40%	33%	-	0%	0%
Columbia River	Sport	189	181	88	116	95	1427	890	499	1289	691	**13%**	20%	**18%**	**9%**	**14%**	80%	26%
	Net	711	186	178	93	123	2701	1214	1205	896	690	26%	**15%**	**15%**	**10%**	**18%**	80%	36%

3.4.6 Historic CWT data gaps

There are not any concerning information gaps for the Okanagan CWT indicator stock (SMK). This stock has CWT releases starting in brood year 1989 and there are only three cohorts since then (1996, 1998 and 2001) with no CWT releases. While the CTC prefers to have CWT releases prior to their 1979–1982 base period, this is not an issue for the Okanagan stock since it is currently not represented as a single stock in the PSC Chinook Model.

3.4.7 Marine insights

Overall, the metrics derived from the ERA do not indicate any alarming trends. Release to age-3 survival estimates for complete broods with all ages returned have been relatively stable. Brood year ocean exploitation rates have been steadily declining since brood year 2007. The mortality distribution tables show an increase in the percentage of Chinook escaping to the spawning grounds since calendar year 2014. Trends in maturation rates do provide some concern as these indicate that summer Chinook are returning at younger ages which may result in declines in overall productivity through mechanisms such as lower fecundity.

The current CWT-based exploitation rates for Okanagan Chinook only represent the impacts of fisheries on the adipose fin marked fish during the years when mark selective fisheries have occurred in the Columbia River and ocean fisheries. This is a known limitation with the current CWT-based exploitation rate data and the PSC's CYER Work Group is currently developing methods to account for mark selective fishery (MSF) impacts and report the exploitation rates for unmarked Chinook, which will represent exploitation rates on natural origin Okanagan summer Chinook. The Columbia River sport fishery on summer Chinook has been primarily mark selective since the early 2000s. Because of this, the exploitation rates on natural origin fish in the Columbia River are likely over-estimated by metrics such as the mortality distribution table. The CYER Work Group is developing solutions that will account for MSF impacts and they plan to have solutions implemented in the CTC's ERA computer programs in the coming years once methodical details are reviewed and finalized.

The derived metrics reported in this section highlight the value of CWT efforts. The OWG recommends that these tagging efforts continue to provide a robust time series of marine survival related information.

3.5 Adult Migration and Holding

3.5.1 Migration and holding in United States waters

Upper Columbia summer/fall Chinook originating upstream of Wells Dam typically enter the Columbia River from late May to late July, with an average 50% passage date at Bonneville Dam of June 30th (Columbia Basin Research 2022). Upstream migration through the Columbia River typically takes approximately 2–3 weeks, resulting in a 50% passage date at Wells Dam of July 17th (Columbia Basin Research 2022). Summer Chinook destined for the Okanagan River typically encounter a thermal barrier at the confluence of the Okanagan and Columbia Rivers which disrupts their migration and causes a portion of the population to hold in the Columbia

River for 1–6 weeks (Pearl et. al. 2022). Based on mean daily temperatures and an assumed migration barrier of 22°C, there are an average of 17 days (July 1–18) in which adult summer Chinook can enter the U.S. Okanagan, but cannot enter the Canadian Okanagan (Figure 14) and most of these fish hold in the cooler waters of the Similkameen River until they spawn (Figure 15). PIT tag data suggest that fish will stop migrating into the Okanagan River when the temperature at the USGS gage at Malott is approximately 22°C (Figure 16). When rain or a cold front causes a brief period of cooler temperatures the lower Okanagan River temperature will drop below 22°C for a time period ranging from hours to days, and summer Chinook migration from the Columbia will occur.

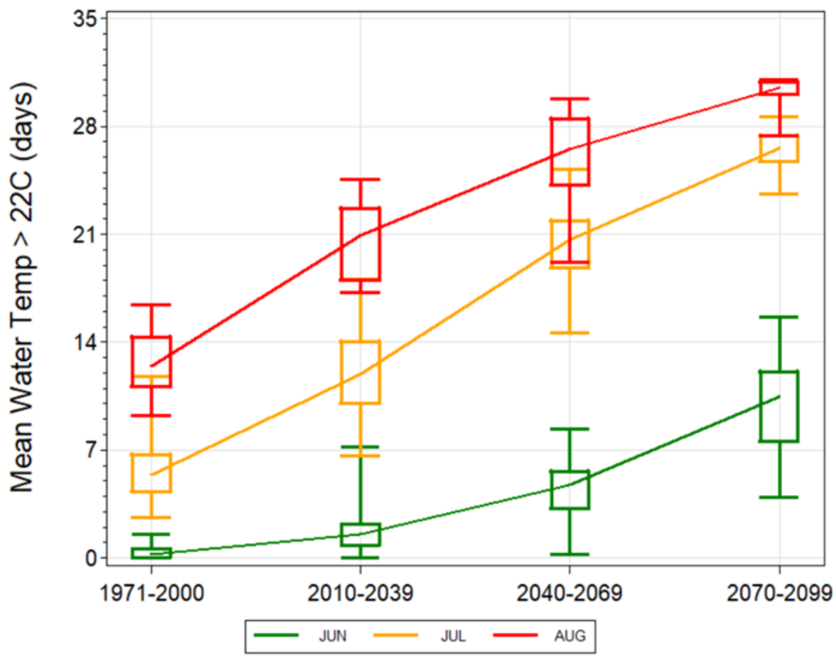

Figure 14. Time trends in the projected frequency of days when water temperature in the lower Okanagan River (Malott, WA) would exceed 22°C, by month, based on an ensemble of 20 CMIP5 Global Climate Models for the 'pessimistic' (RCP8.5) high greenhouse gas emission scenario (Stiff et al., in prep).

Figure 15. The lower Similkameen River habitat where adult Chinook Salmon hold during the summer months until the Okanagan River temperatures cool in the fall and then the Chinook migrate downstream to their spawning areas in Okanagan and Similkameen rivers.

In many years, there will be one or more ‘breaks’ in the thermal barrier during which a portion of the fish holding in the Columbia River will ascend the Okanagan River (Figure 16). The Similkameen River is the primary pre-spawn holding habitat in the U.S. portion of the Okanagan River, which is typically 2–3°C cooler than the Okanagan River (

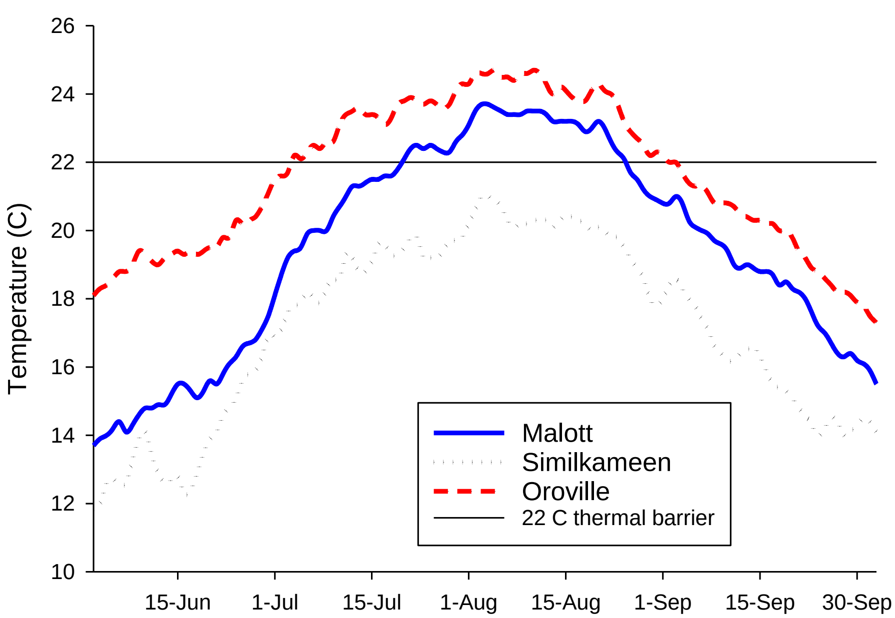

Figure 17). However, for fish destined for Canada, a secondary thermal barrier exists at the outlet to Osoyoos Lake which typically begins earlier and lasts longer than the barrier in the lower Okanagan (

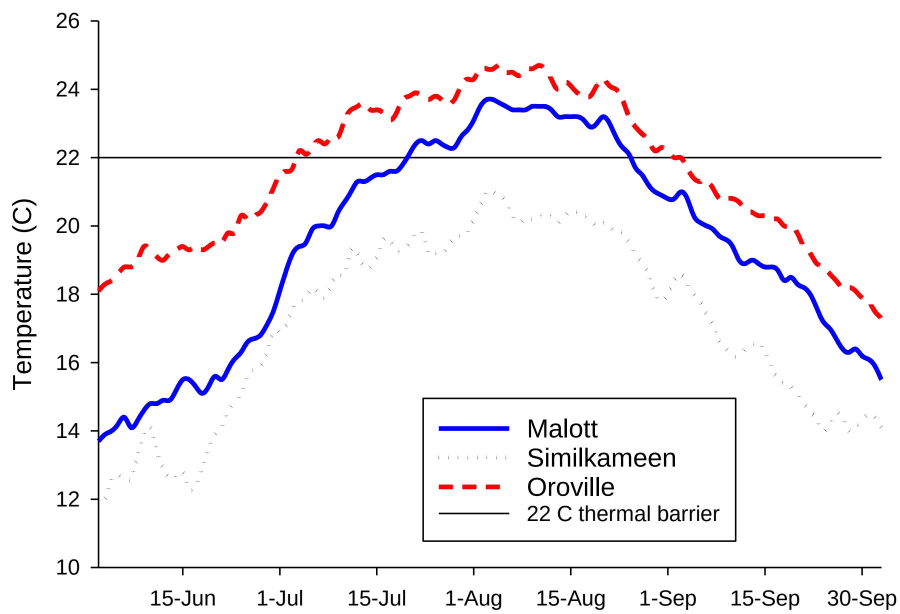

Figure 17). The thermal barrier breakdowns that sometimes occur in the lower Okanagan do not typically occur at the outlet of Osoyoos Lake, as indicated by temperature data from the USGS gage at Oroville, Washington (Figure 18). This unique spatial and temporal temperature dynamic likely results in summer Chinook that are destined for Canada having to complete a portion of their pre-spawn holding in either the Columbia or Similkameen rivers. It is possible that utilizing the Similkameen River for thermal refuge could lead to a higher stray rate to that system, thereby undermining adult escapement to the Canadian Okanagan, or these fish may resume their upstream migration when the water cools in the fall prior to the spawning season. Our assessment of temperature and run timing for summer Chinook destined for Canada suggests that, on average, 1–3% would make it into Canada before the thermal barrier sets up, 25–27% would use the Similkameen for pre-spawn holding and approximately 70% would need to pre-spawn hold in the Columbia River until late August each year. These conditions may lead to a climate adaption of earlier migration timing for fish returning to spawn in Canada.

Despite the challenging migration and pre-spawn holding conditions, there is little evidence of extensive pre-spawn mortality. Several radio tracking studies were implemented in 2005, 2011 and 2012 which did not reveal many fish that likely expired before the spawn period (Ashbrook et al. 2008; Mann and Snow 2018). In recent years, the Chief Joseph Hatchery monitoring staff have conducted float surveys before the spawning season in September and not very many carcasses have been observed (Andrea Pearl, Personal Communication).

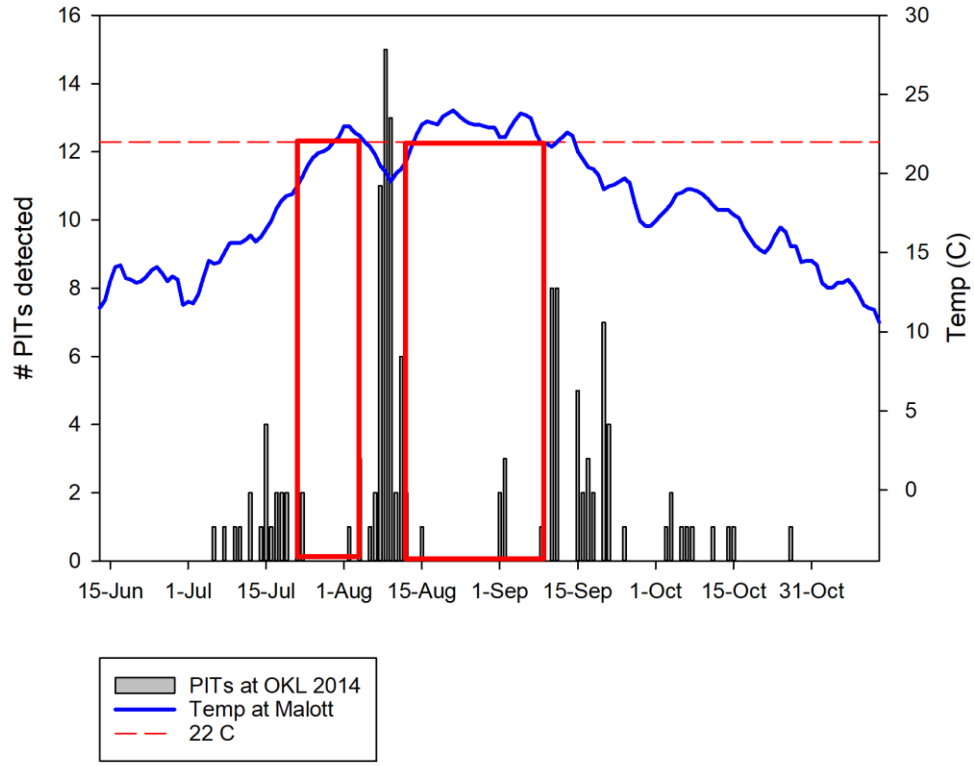

Figure 16. Detections of summer Chinook at the Lower Okanagan PIT array (OKL) in 2014 at Malott, WA.

Note: Red boxes indicate periods when the temperature at the United States Geological Survey (USGS) gage in Malott exceeds 22°C which appears to stop upstream migration for most summer Chinook.

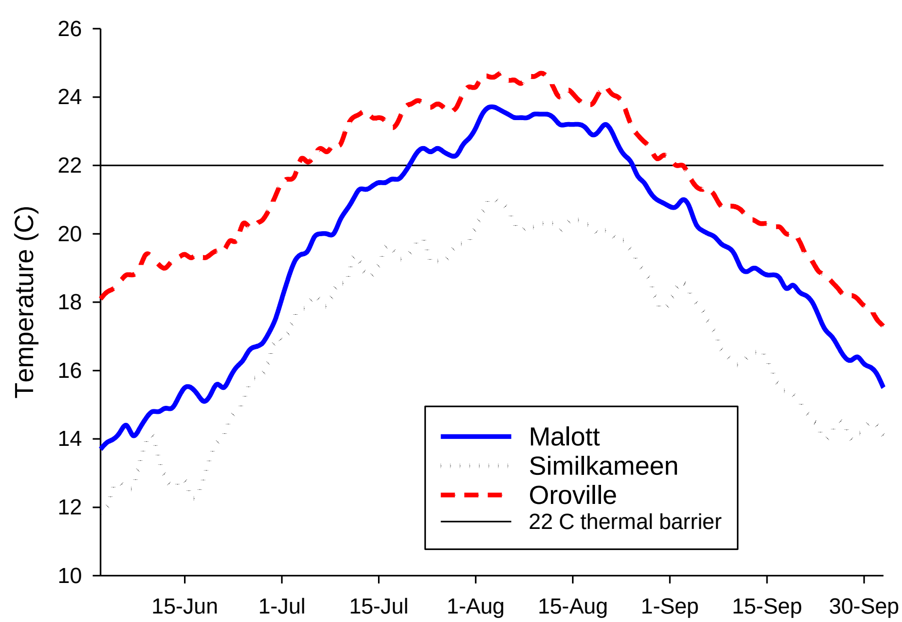

Figure 17. Mean daily temperature at United States Geological Survey (USGS) gaging stations in the lower Okanagan River (Malott), the Similkameen River and near Oroville (just downstream of Lake Osoyoos) from 2007–2019.

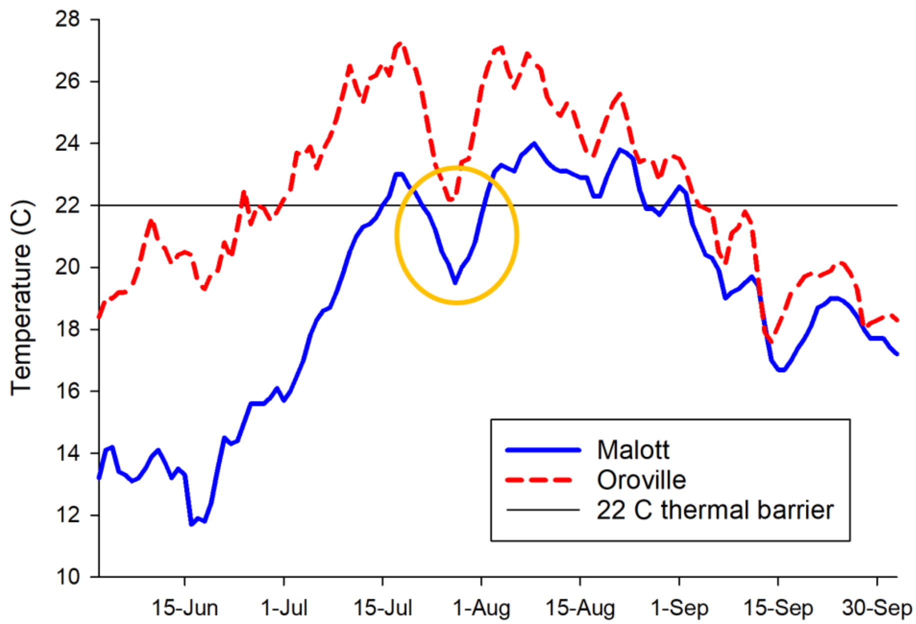

Figure 18. Mean daily temperature at 2 United States Geological Survey (USGS) gaging stations in 2014 showing the thermal barrier break down that can occur in the lower Okanagan (yellow circle) that does not necessarily extend to fish that might be destined upstream of Lake Osoyoos.

The Enloe Dam in Washington remains a barrier to Chinook attempting to migrate upstream in the Similkameen River (Figure 19). Chinook have been observed upstream of Coyote Falls and jumping at the base of the dam, and hydraulic modeling has identified multiple salmon migration routes over and around the falls depending on river discharge. Several feasibility and planning studies for the potential removal of Enloe Dam are underway, which are aimed at access, water management, sediment management, sediment contaminants, structure removal and site restoration and rehabilitation. If the dam is removed and Coyote Falls are passable by Chinook, then salmon will have access to over 100 km of spawning and rearing habitat in the relatively intact Similkameen River watershed. This would increase the productive capacity for Okanagan summer Chinook and the abundance of Chinook for fisheries for both countries. Currently, efforts are focused on understanding the level of contaminants in the sediment, as this will greatly affect the options, biological and social risks, and cost of the dam removal.

Figure 19. Enloe Dam on the Similkameen River lies a short distance upstream of Coyote Falls, near the truck parked by the dewatering pipes that have been constructed along the right bank.

3.5.2 Migration and holding in Canadian waters

Osoyoos Lake undergoes a temperature-oxygen squeeze in nearly all years, reducing available lake habitat for migrating fish. Generally, the central and south basins of the lake become unusable. This is not an issue for Skaha and Okanagan Lakes, and little is known about the situation with Vaseux Lake. From mid-July to the third week of August, temperatures in the Okanagan River at Oliver typically exceed 22°C. There are many small groundwater seeps, primarily in the natural section, but no cold, deep holding areas. ONA Elders have mentioned that putting the river back to a natural state will reconnect it to thermal refuges.

Once adult summer Chinook make it as far upstream as the North Basin of Osoyoos Lake they have options for pre-spawn holding with adequate temperatures including the thermocline of Osoyoos Lake, the natural reach of the Okanagan River between Skaha and Osoyoos Lake, and cool water tributary confluences with the Okanagan River.

There are several low head dams in the Canadian Okanagan including 17 VDS, McIntyre Dam, Skaha Lake Dam and Okanagan Lake Dam. VDS present unfavorable hydraulic conditions for both juvenile and adult migrants. For adults, laminar flow over the crest hampers passage and unnatural plunge conditions prompt fish to jump prematurely and fall short of the crest. Adults spawning upstream of Skaha Lake have to pass McIntyre Dam and migrate up the fish ladder at Skaha Lake Dam. While improvements have been made to McIntyre Dam to increase fish jumping success, improvements to the fish ladder at Skaha Lake Dam are needed to reduce migration delay times, access to cool waters in Skaha Lake, and ultimately to improve migration survival and spawning success. The extent of this problem is unclear. The fish ladder at Okanagan Lake Dam has been activated for several years on a trial basis to determine passage success and inform whether improvements are needed to optimize passage. Any impacts would be cumulative to the numerous fish ladders and structures these fish have already passed on their migration up the Columbia River.

3.5.3 Pinniped predation

Pinniped predation on adult salmonids in the Columbia River estuary has been a topic of growing concern in recent years. Several studies have been conducted suggesting that the majority of impact of pinnipeds occurs on spring Chinook salmon, due primarily to the timing and distribution pattern of California sea lions near Bonneville Dam (Keefer et al 2012; Wargo Rub et. al. 2019; Brown et al 2020). Therefore, unless pinniped behavior changes in the future, it does not appear they are a major threat to adult summer Chinook migration survival and abundance.

3.5.4 Climate change

Climate change poses a major threat to summer Chinook adult migration and subsequent spawning success. Global Climate Model (GCM) projections[3] of daily air temperature were statistically-converted to daily mean water temperature at key sites along the Okanagan Chinook migration corridor. The results suggest potential water temperature increases of 3–5°C during July and August in the lower Okanagan River by 2040–2069, relative to the 1971–2000 reference period (Abatzoglou and Brown 2012; Hyatt et al. 2020; Stiff et al. in prep). Perhaps more important than the absolute increase in water temperature is the increase in the frequency and duration of time in which the Okanagan River exceeds 22°C, blocking upstream migration. Downscaled GCM outputs for the more pessimistic climate change scenario (Representative Concentration Pathway [RCP] 8.5) indicate that during the 2040–2069 time step, the median frequency of days exceeding 22°C in the Okanagan River may increase from 5 days to 21 days in July, and from 12 to 26 days in August, relative to the reference period (Figure 14). The median duration of migration-blocking 22°C 'thermal barrier' events may double in length, from 10 days per event (in the reference period) to about 20 days (range: 12-42 days) by the 2040-2069 period (Figure 20).

[3] Based on GCM air temperature time-series (January 1, 1950-December 31, 2099) from an ensemble of 20 Coupled Model Intercomparison Project Phase 5 (CMIP5) GCMs obtained from the University of California Climatology Lab data portal (Climatology Lab, University of California 2022), using a modified Multivariate Adaptive Constructed Analogs (MACA v2) method for GCM data downscaling and bias-correction (Abatzoglou and Brown 2012). Downscaled and bias-corrected GCM air temperature data were statistically converted to water temperature via nonlinear regression modelling (Hyatt et al. 2015; Stiff et al. in prep).

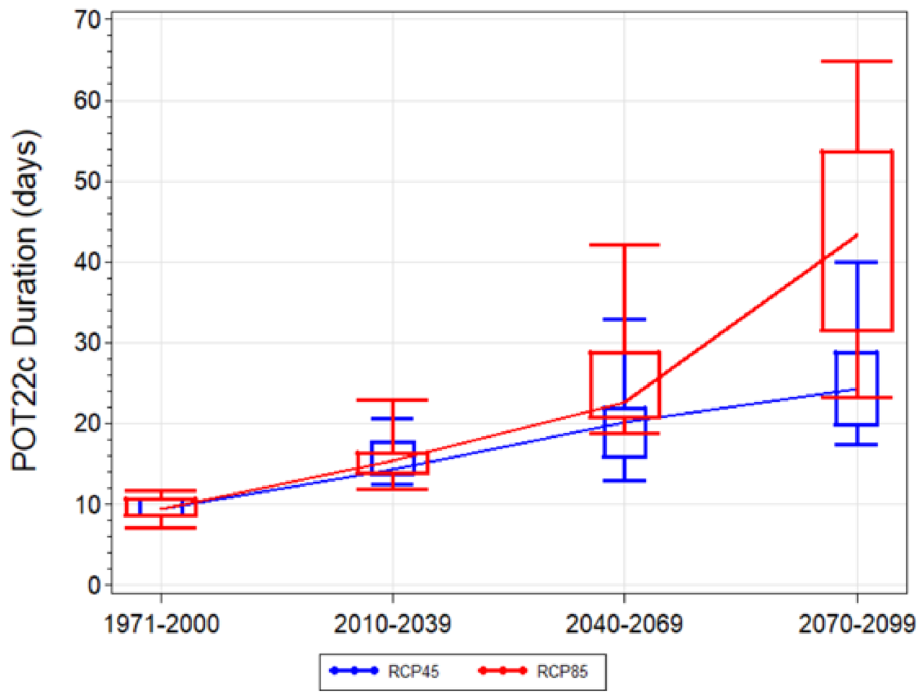

Figure 20. Time trends in the projected duration of continuous days when water temperature in the lower Okanagan River, (near Malott, WA) would exceed 22°C (POT = peak over threshold), based on an ensemble of 20 CMIP5 Global Climate Models for 'low' (RCP4.5) and 'high' (RCP8.5) greenhouse gas emission scenarios (Stiff et al., in prep).

The Okanagan summer Chinook population relies on several cool water areas for holding from late June until the warm Okanagan River temperatures cool in September before the spawning period. The large lakes in Canada, the lower Similkameen River (Figure 15), and the mainstem of the Columbia River at Pateros Lake (Wells Pool) provide cool water pre-spawn holding habitats, which will likely be affected differently by climate change. The largest impacts to cool water pre-spawn holding habitat are anticipated for the Similkameen River and Pateros Lake, but impacts are uncertain for the temperature-oxygen squeeze in the north basin of Osoyoos Lake, whereas negligible effects are expected in Skaha and Okanagan Lakes. Chinook will have to maintain pre-spawn holding in these locations for longer periods until the Okanagan River cools sufficiently, and the temperatures will increase during the summer holding period. Currently 'tolerable' July–August water temperatures in the Similkameen (median <18–19°C) will likely exceed 20°C by the 2050s, and median June and September temperatures may approach 18°C by the end of the century, under the pessimistic RCP 8.5 scenario (Stiff et al. in prep). If Similkameen River temperatures rise as predicted it could reduce pre-spawn holding survival for the population and apply strong selective pressure towards a fall run timing.

Under current conditions, holding in Pateros Lake may not be a problem, however, projected water temperature increases in the mid-Columbia mainstem due to climate change could have devastating effects on the Okanagan summer Chinook population. Mean water temperatures in the mostly isothermal Pateros reservoir during July–August averaged 17.5 ± 1.5°C in recent decades (1993–2019) and averaged 18–19°C in hot years (e.g., 1998, 2003, 2015) (Hyatt et al. 2020). Isaak et al. (2017) and Environmental Protection Agency (EPA 2020) models projected water temperatures in the mid-Columbia to increase 1°C by the 2050s relative to the reference period, thereby consistently elevating water temperatures to thermally stressful levels of 18–20°C in key holding habitat for salmon above Wells Dam.

3.5.5 Adult migration and holding insights

A complex set of conditions affect the upstream migration rates and survival for Okanagan summer Chinook, and climate change will likely exacerbate the situation and lead to slower migration rates and longer delay periods with the anticipated longer thermal barrier in the Okanagan River. Accordingly, there are several potential mitigations to consider including those that ease and shorten the migration time to the cold water refugia in the Okanagan, and others related to fisheries management and hatchery broodstock collections.

Upstream migration rates can be improved directly by activities such as modifying or removing VDS and improving passage conditions at the low head dams. The migration rates can also be improved indirectly by reducing the magnitude of, or shortening the duration of, the thermal barrier and by increasing the quantity of colder water habitat for summer Chinook while they are holding near their spawning grounds. Several actions can help to alleviate the effects of warm water temperatures and provide more cool water refugia, such as reconnecting and expanding cool water inputs and refuges from colder tributaries, improving irrigation efficiencies and changing points of diversion to reduce water withdrawals from cold water tributaries, and by reconnecting the main river channel floodplain habitats, and restoring riparian habitats. Other large-scale options include changing Osoyoos and Vaseux Lake level management, implementing cold water siphons from lakes in Canada (e.g., Skaha), constructing high elevation reservoirs on tributaries that could release cool water in the summer months and removing Enloe Dam to increase the amount of cold water habitat.

Management of the fisheries in the Okanagan River and nearby portions of the Columbia mainstem may have the flexibility to consider the run timing components of the Okanagan summer Chinook differently. The early migrating component is more likely to experience suitable Okanagan River temperatures prior to the onset of the thermal barrier, and these fish are more likely to reach the cool water habitats in the Canadian lakes and the Similkameen River. This may also help promote early run timing for summer Chinook in Canada. In comparison, the later migrating components are likely to experience the thermal barrier and hold in the mainstem of the Columbia River during July and August until Okanagan River temperatures cool near the end of August, when the Chinook resume their upstream migration to the spawning grounds.

Our knowledge about the role of river temperatures on adult Chinook migration will be improved by continuing to apply PIT tags to Chinook released in Canada and the U.S. and subsequently tracking the adults at the detection arrays at Omak, Zosel Dam, and other locations in the Okanagan. Additionally, the installation of a PIT tag array in the Similkameen River upstream of the Okanagan River confluence could increase our knowledge about the use of Similkameen summer holding area by Okanagan Chinook relative to river temperature, and to provide a baseline of information for planning climate change mitigations. Currently, much of the Canadian hatchery production is marked with PIT tags to support several objectives, including survival monitoring and the spawner escapement estimation program (i.e., mark-recapture methodology, McGrath and Yuan 2020), which ultimately contribute to population rebuilding. Since the PIT-tagged fish are very important and valuable for multiple objectives, it would be particularly helpful if U.S. management entities scanned broodstock and surplus collections for tags and returned the Canadian PIT tagged Chinook to the river to continue their migration. The returning Canadian hatchery summer Chinook with PIT tags are extremely valuable, especially when the abundance of adult Chinook spawners is very low in the Canadian Okanagan River.

3.6 SPAWNING

Accurate escapement estimation is critical for assessing stock status, monitoring productivity, and documenting the rebuilding of Okanagan Chinook salmon in Canada and critical for managing population levels in the U.S. Currently, both estimates of escapement in Canada and the U.S. do not meet CTC standards for precision (CV ≤ 15%) or accuracy and neither includes an estimate of uncertainty due to the methods applied in both countries. Fish passage improvements in Canada occurring since 2009 at McIntyre Dam, 2014 at Skaha Dam, and possibly in 2021 for the Okanagan Dam have opened up new sections of the Okanagan River for spawning and rearing in the Canadian portion of the river. Time series of Canadian abundance indices based on Area-Under-the-Curve estimates indicate that since 2006, the population has ranged from <10 individuals to 80 individuals with hatchery-origin fish averaging 8% and ranging from 0–23% interannually (Figure 21; Table 12). However, the PIT mark-recapture estimate for 2020 was approximately 200 individuals (McGrath and Yuan 2020), and this new escapement methodology has been designed to meet the CTC data standards for escapement indicator stocks. U.S. abundances based on redd counts have ranged between approximately 1,000 to 14,000 since 1998 with hatchery contribution ranging between 10–68% (Figure 22; Table 12). Reliable estimates of abundance are needed to support hatchery supplementation planning efforts in both countries.

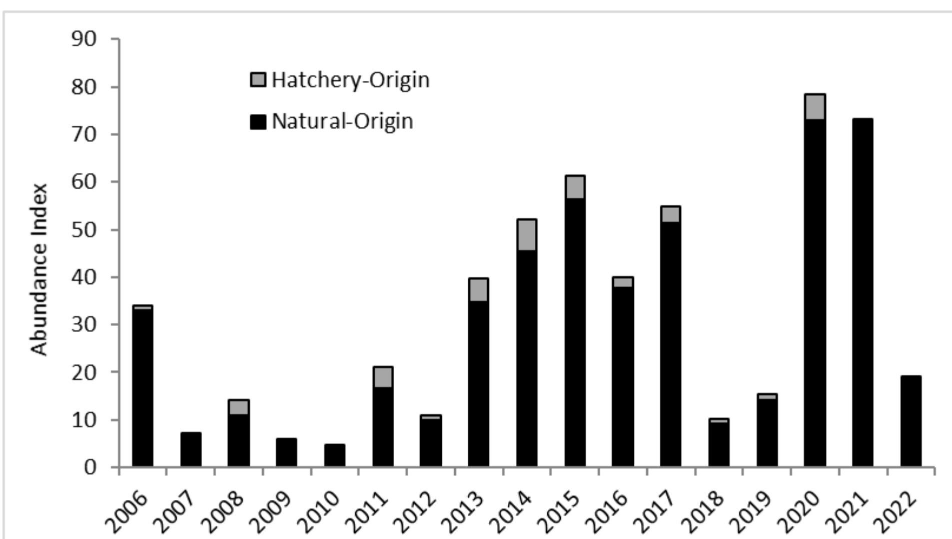

Figure 21. Estimates of natural- and hatchery-origin adult escapement of Okanagan Chinook salmon in Canada, 2006–2022.

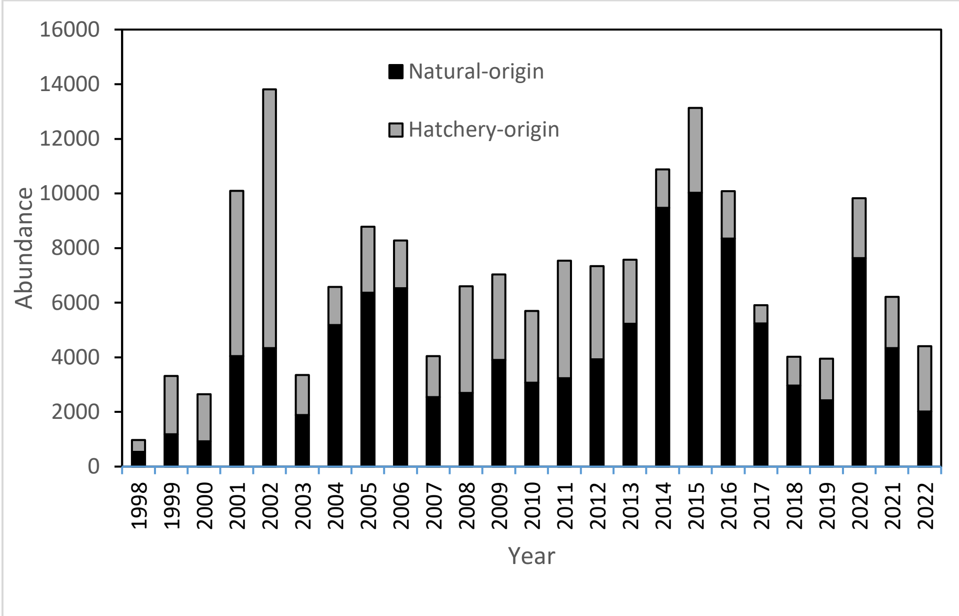

Figure 22. Estimates of natural- and hatchery-origin adult escapement of Okanagan Chinook salmon in the United States, 1998–2022.

Table 12. Canadian and U.S. natural- and hatchery-origin Okanagan Chinook adult spawner estimates by year.

	Canada		United States	
Year	**Natural-Origin Spawners**	**Hatchery-Origin Spawners**	**Natural-Origin Spawners**	**Hatchery-Origin Spawners**
1998			542	437
1999			1182	2142
2000			926	1726
2001			4048	6047
2002			4337	9473
2003			1892	1463
2004			5182	1392
2005			6364	2416
2006	33	1	6536	1741
2007	7	0	2539	1509
2008	11	3	2696	3902
2009	6	0	3903	3130
2010	5	0	3076	2623
2011	17	4	3233	4304

Year	Canada		United States	
	Natural-Origin Spawners	Hatchery-Origin Spawners	Natural-Origin Spawners	Hatchery-Origin Spawners
2012	10	1	3933	3408
2013	35	5	5233	2336
2014	46	7	9470	1405
2015	56	5	10021	3110
2016	38	2	8352	1734
2017	51	4	5239	672
2018	9	1	2972	1044
2019	14	1	2422	1535
2020	73	6	7639	2193
2021	73	0	4344	1870
2022	23	0	2002	2390

The Canadian portion of the Okanagan River is extensively channelized, and flows are highly controlled using 17 VDS and 3 dams. A “natural” and “semi-natural” section of the river is used as an escapement index and these sections in conjunction with the Penticton Channel are surveyed annually by boat and river walks for Chinook escapement. At the VDS, observers count all live Chinook visible upstream of the structure. Escapement estimates in Canada have historically been generated via Area-Under-the-Curve (AUC) methods with a survey life of 7.7 days. Survey life was selected from the literature (Nielson and Green 1981); actual survey life is unknown and is assumed to be biased low. Escapement estimates generated using this methodology assume that 1) observer efficiency is 100%, 2) survey life is accurate, and 3) spawning occurs in the natural and semi-natural reaches only, and not in any of the un-surveyed areas. Currently, no expansion factor is applied to the abundance estimate to account for areas that are not surveyed due to the lower quality of habitat in the unsurveyed reaches. Biological samples are collected via 10 carcass recovery surveys each year in index reaches. Carcass surveys support the assertion that AUC estimates are likely biased low.

In 2020, the ONA implemented a PIT-tag mark-recapture program to improve escapement estimation to the Canadian Okanagan, which is designed to meet the CTC data standards for escapement indicator stocks if 15,000 to 18,000 PIT tags are applied each year. This escapement estimation method assumes that 1) either or both samples (carcass survey and detection at PIT array) are a simple random sample, 2) the population is closed, 3) there is no tag loss during spawning, 4) tagging status of each recovered fish is determined without error, 5) tagging has no effect on the behavior of the fish, and 6) carcass sampling rates do not vary by sex and size.

Although the PIT-tag mark-recapture method has the potential to meet the CTC data standards, issues with the supply of Okanagan Chinook eggs to the ONA kł cp̓əlk̓ stim̓ Hatchery in Penticton have resulted in fewer tags applied than is optimal for the study design (Table 13). Chief Joseph Hatchery is currently the primary supplier of Okanagan Chinook eggs to the ONA kł cp̓əlk̓ stim̓ Hatchery for rebuilding the Canadian portion of the population, but they can experience high mortality issues due to warming well water during broodstock collection. Improvements to the

Chief Joseph Hatchery, particularly to the water system, would help hatchery programs on both sides of the border and allow for a greater probability of being able to transfer the targeted number of eggs to the ONA. Other such mitigation options to ensure the ONA receives sufficient eggs could include examining the feasibility of holding broodstock in the Similkameen River ponds in Oroville (which would require the construction of an adult holding facility), broodstock collection at Zosel dam, and improved broodstock collection in the Canadian Okanagan by the ONA.

Table 13. Chinook PIT-tagged and total releases from the Okanagan Nation Alliance kł cp̓əlk̓ stim̓ Hatchery.

Brood Year	Release Timing	Age	Total Release	PIT Release
2016	Jun-17	subyearling	10,396	3,417
2017	Jun-18	subyearling	3,383[1,2]	0
2017	Apr-19	yearling	8,220	8,220
2018	-	-	-	-
2019	Nov-20	large subyearling	20,390	4,728
2019	Apr-21	yearling	21,847	17,225
2020	Apr-21	subyearling	6,137[3]	0
2020	Jan-22	yearling	22,550	22,550
2021	May-22	subyearling	350[4]	0

[1] All coded-wire tagged.
[2] 1218 from Canadian Okanagan River broodstock.
[3] All from Canadian Okanagan River broodstock and thermal-marked.
[4] 2896 acoustic-tagged and all thermal-marked.

In the U.S., the entire spawning area is surveyed from the confluence with the Columbia River to Chief Joseph Dam, the Okanagan River from the confluence to Zosel Dam, and the Similkameen River from the confluence with the Okanagan to Enloe Dam. There are eight reaches surveyed over the entire spawning period (late September through early November). Spawning escapement is based on counts of redds multiplied by sex ratios from Wells Dam. Redd counts are conducted using aerial surveys once per week throughout the spawning season with trained observers and using five float surveys throughout the spawning season. Redd locations are recorded using GPS to ensure aerial surveys do not duplicate float counts. Escapement estimates are based on the assumptions that 1) each female produces one redd, 2) 100% of redds are counted, and 3) the sex ratio at Wells Dam, which includes jacks, matches the ratio on the Okanagan River spawning grounds.

Redd count based escapement methods tend to produce escapement estimates that are biased low (PSC Sentinel Stocks Committee 2018), and some discrepancies have been identified between the lower redd-based escapement estimates upstream of Wells Dam (Okanagan, Methow, and mainstem Columbia spawners) and the higher counts of summer Chinook at Wells Dam. In the U.S. Okanagan, surveys have very good spatial and temporal coverage, therefore the main components of uncertainty arise from the accuracy of the redd counts in the reaches with high redd density and the accuracy of the Wells Dam sex ratio to represent the Okanagan River spawners. For example, in 2018 the ratio of males per female was 0.46 at the Okanagan River spawning grounds based on carcass sampling (n=547) compared to 1.30 for live fish at the Wells Dam trap (n=1,047), which produced estimates of Okanagan summer Chinook escapement of 3,089 and 4,860, respectively (Appendix C; Escapement Workshop). Redds can be difficult to accurately identify and count when densities are high and when they are superimposed, and there can be inter-observer variability in the redd counts and identification (Figure 23). For example, Figure 23 identifies 48 redds using black circles, but there are other areas where the Chinook have moved gravel or washed the algae off the gravel as indicated by the light grey gravel. Counting of redds is another source of error, as indicated by the recorded count of 47 on the figure when 48 circles were used to identify redds.

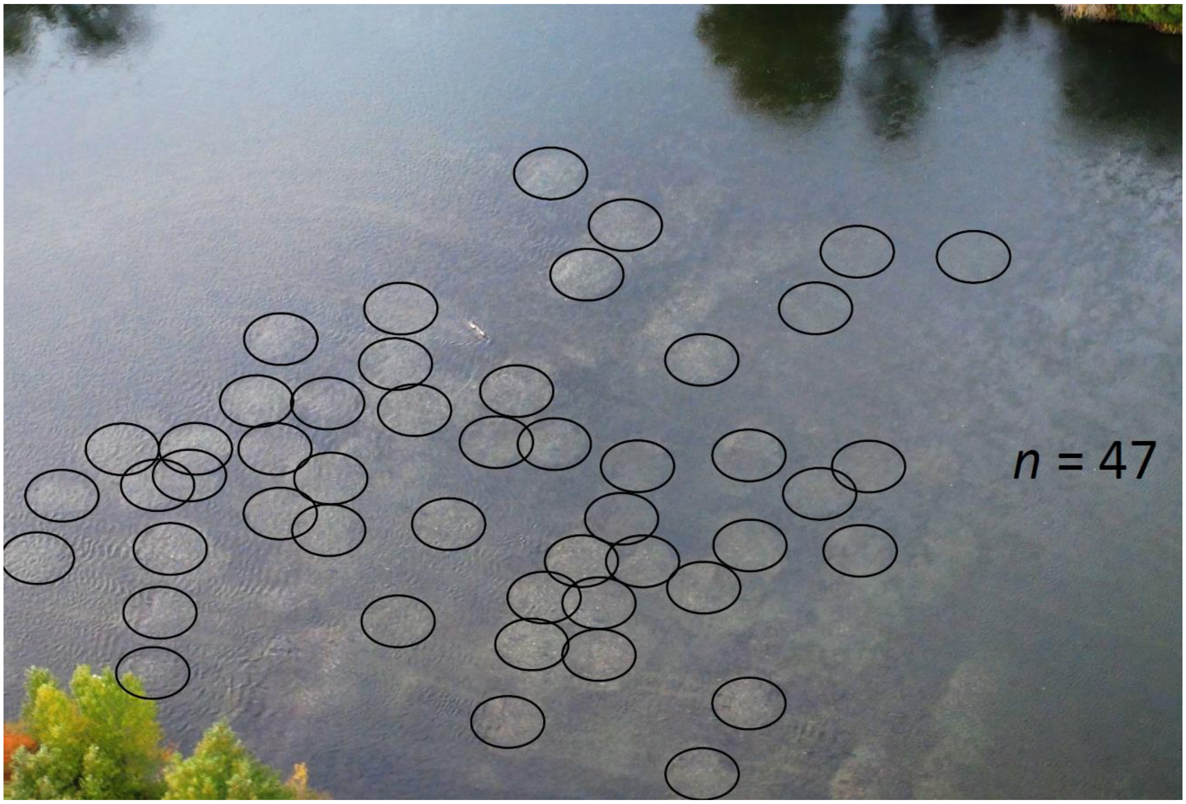

Figure 23. Photograph of high-density Okanagan summer Chinook redds counted, as indicated by black circles, and actual areas of the river gravel that were disturbed by summer Chinook, as indicated by the light grey gravel where most of the algae was removed from the rocks (Escapement Workshop; Matthew Laramie and Andrea Pearl).

Improvements to the quality of the escapement estimates in the U.S. Okanagan can be informed by recent studies happening elsewhere in Washington State. Work is underway to improve redd-based escapement methodologies on the Methow and Wenatchee rivers and management entities could collaborate and learn whether or not these methods could be applied to Okanagan Chinook. The Okanagan Work Group discussed the potential for a genetic mark-recapture study but there are likely issues with catch variability in the smolt monitoring program to consider with this method. There are case studies available on the Stillaguamish, Snoqualamie and Nooksack rivers using transgenerational genetic mark-recapture methods that should be examined for potential application to Okanagan River Chinook escapement. Alternatively, a PIT mark-recapture in the U.S could potentially improve escapement estimates and also make use of existing infrastructure for steelhead and spring Chinook. Additionally, substantial improvements could likely be made by improving methods used to estimate sex ratios or to account for the uncertainty in the sex ratios on the spawning grounds and at Wells Dam. Although several potential improvements to escapement programs exist, any new methodology to improve estimates for Okanagan Chinook in the U.S. should run concurrently with the existing programs to ensure their efficacy and to potentially calibrate historic escapement estimates. The financial cost of addressing the uncertainties associated with escapement estimates in the U.S. could be high.

In addition to uncertainties associated with the escapement estimates themselves, there is also limited spawning habitat available for Chinook salmon in Canada due to the channelization and flood control dikes. This amount of spawning habitat is not limiting the abundance of spawners currently, but it may become an issue as the population rebuilds. Okanagan summer Chinook have the highest abundance of spawners in the reaches of the Okanagan River below Zosel Dam to the Similkameen confluence (2006–2019 mean of 30%), the reach immediately downstream of the Similkameen confluence (2006–2019 mean of 21%), and the lower Similkameen River (2006–2019 mean of 21%; Figure 24). The high distribution of spawning in this area is attributed to the high-quality gravel in these reaches, especially in the Okanagan River from Zosel Dam to the Similkameen confluence, to the presence of nearby cold water refuge habitat in the Similkameen River, and to the nearby location of the Similkameen Hatchery pond. Large lakes stabilize discharge by buffering flood effects and reducing stream bank erosion and bedload movement compared to systems with highly variable discharge regimes (Montgomery et al. 1996), and they can trap fine sediments that adversely affect egg-to-fry survival (Chapman 1988). Thus, spawning habitat quality and egg-to-fry survival can be relatively higher in large-lake moderated systems than small- or no-lake moderated systems (Holtby and Healey 1986; Chapman 1988; Montgomery et al. 1996). Typically, large lakes such as Skaha and Okanagan Lakes, also provide abundant cool water habitat for adult summer Chinook to hold in until river temperatures cool to below 15°C, which is associated with the onset of Okanagan summer Chinook spawning and redd construction, but Osoyoos Lake has relatively little cold water habitat because of the aforementioned temperature-oxygen squeeze (Figure 25).

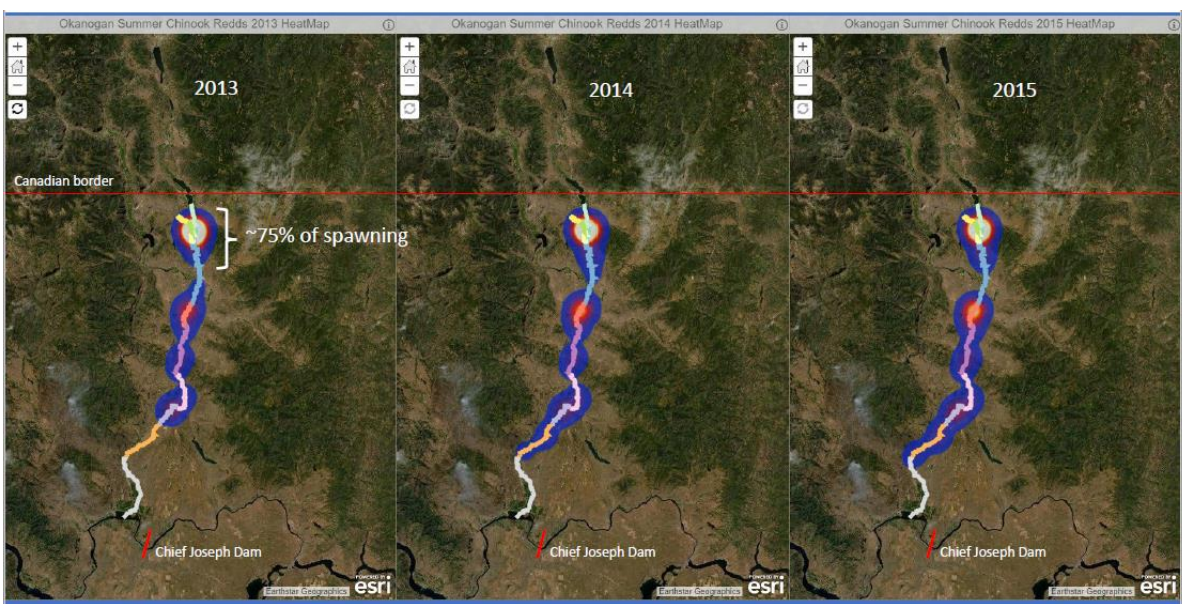

Figure 24. Heat maps of Okanagan summer Chinook redds, illustrating a consistent pattern of the highest densities in the lower reaches of the Similkameen River and the Okanagan River (Escapement Workshop; Matthew Laramie and Andrea Pearl).

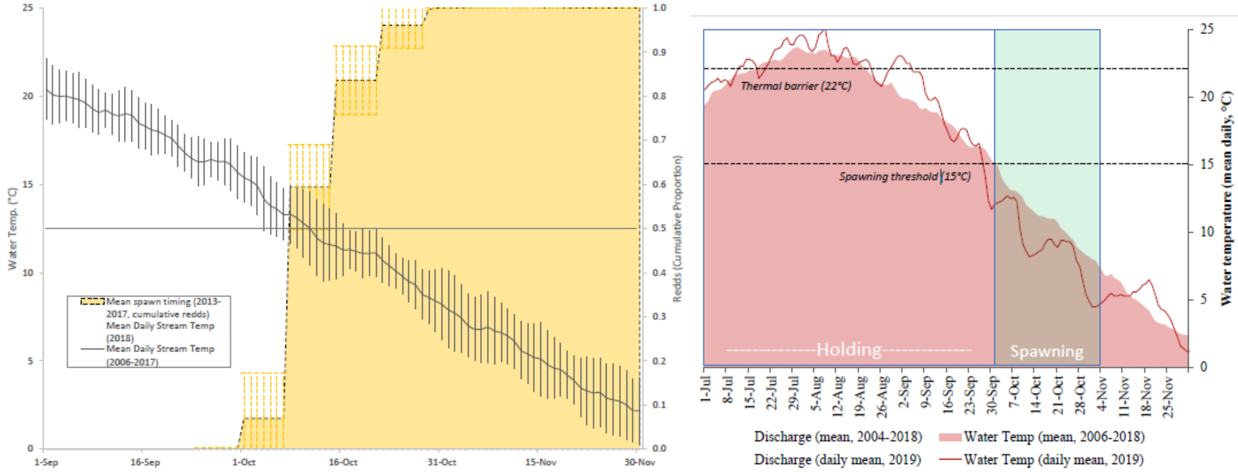

Figure 25. The left panel illustrates the cumulative proportion of Okanagan summer Chinook redds constructed by date, over 2013–2017, along with mean river temperatures, and right panel illustrates recent pattern of daily mean discharge and river temperatures relative to the thermal limits for adult Chinook migration and spawning (Escapement Workshop; Matthew Laramie and Andrea Pearl).

The historical, pre-channelized sections of the Okanagan River in Canada likely had some of the same high quality spawning habitat features in the areas downstream of Skaha and Okanagan lakes that still exist in the U.S. section of the Okanagan, where most of the summer Chinook population spawns. These sections downstream of the large lakes in Canada would have had stable river flows, high quality spawning gravels, and an abundance of cold water refuge habitat nearby in Skaha and Okanagan Lakes. The rebuilding of new, and identification and protection of existing, cold water refugia will be critically important for the survival of spawning Chinook in the temperature sensitive Okanagan River especially under future climate change scenarios. The historic section of the Okanagan River between Skaha and Vaseux Lakes had a sinuous river channel, diverse river habitats with gravel bars and islands, riparian vegetation, and large wood recruitment, especially when compared to the river after it was channelized, with dikes built along both sides of the river and homogenous stream habitat that no longer has the recruitment of gravel and large wood (Figure 26). Restoring the ecosystem function for the sections of the Okanagan River downstream of Skaha and Okanagan Lakes are good opportunities to increase the quantity and quality of spawning habitat for summer Chinook production.

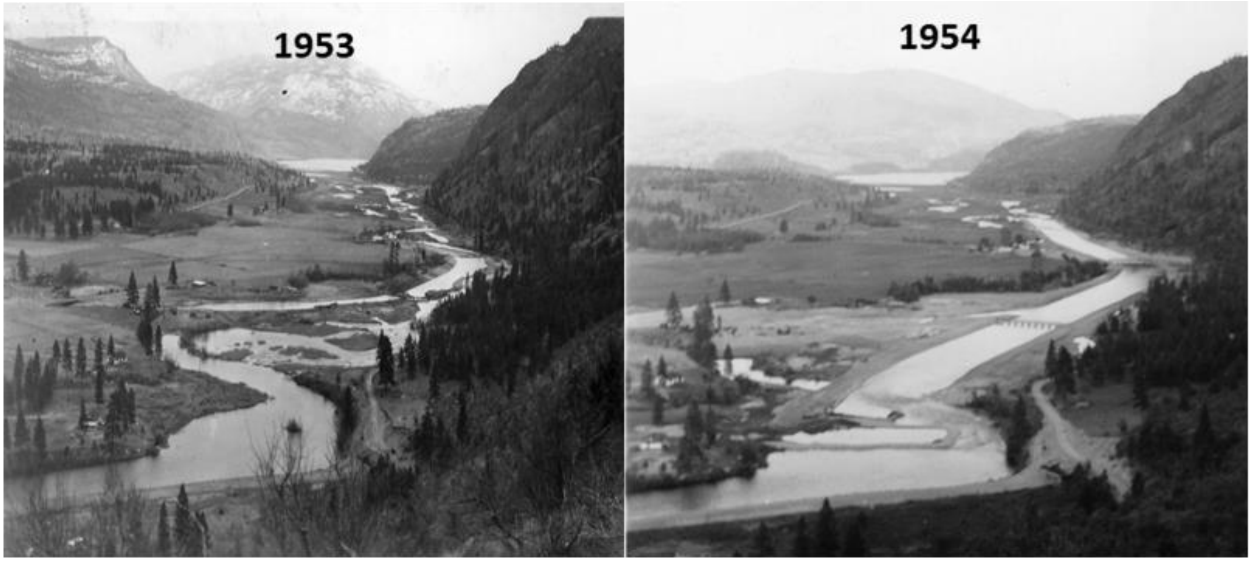

Figure 26. Photographs of the Okanagan River, looking downstream, near the outlet of Skaha Lake (near Okanagan Falls, BC) to Vaseux Lake in 1953 and 1954.

Climate change may impact Chinook reproductive success via elevated water temperatures on the spawning grounds in late September and October. Optimum water temperature for Chinook salmon spawning ranges from 6–14°C (BC Ministry of Environment 2001). Approximately half of the Okanagan summer Chinook spawn in the upper U.S. Okanagan River, with an average (2006–2019) of 30% of the spawners upstream of the confluence of the Similkameen River to Zosel Dam and an average of 21% of spawners in the reach immediately downstream of the confluence. Spawning usually commences after river temperatures drop below 15°C (Figure 27). Water temperatures in the Okanagan River upstream of the Similkameen confluence (USGS 2022a) during peak spawning in October can be 2–3 degrees warmer than downstream of the confluence (USGS 2022b), depending on when high autumn flows in the Similkameen reassert a cooling effect on the lower Okanagan River (Hyatt et al. 2020; Figure 28). An additional 2–3°C due to climate change over the next 30 years (Stiff et al. in prep) could increasingly delay spawning activity, shift peak spawn timing later, and/or restrict the area of suitable spawning habitat to locations below the Similkameen confluence, with likely negative impacts on Chinook salmon reproductive success.

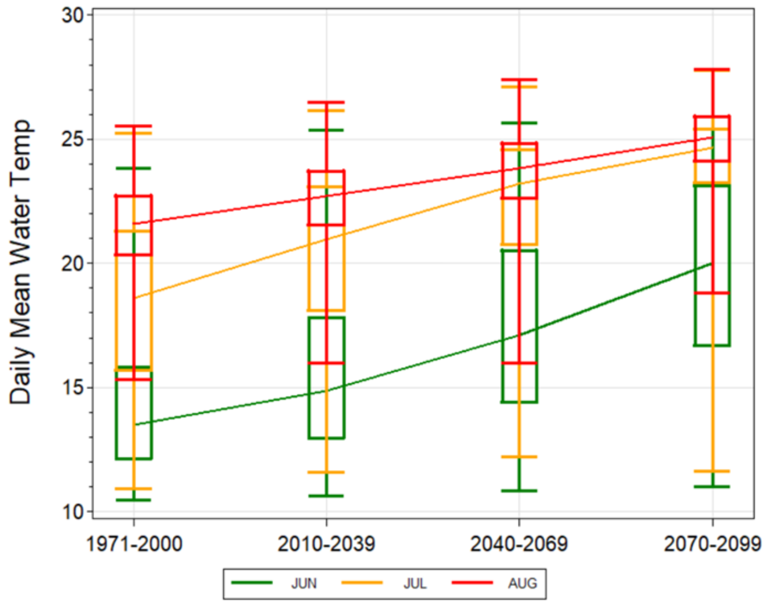

Figure 27. Time trends in lower Okanagan River summer water temperatures (near Malott, WA), by month, based on an ensemble of 20 CMIP5 Global Climate Models (GCMs) for the 'pessimistic' (RCP8.5) greenhouse gas emission scenario. Box plots indicate median (connected by solid line), quartiles (25th & 75th percentiles), and range (T-whiskers) statistics for 20 GCM runs (Stiff et al. in prep).

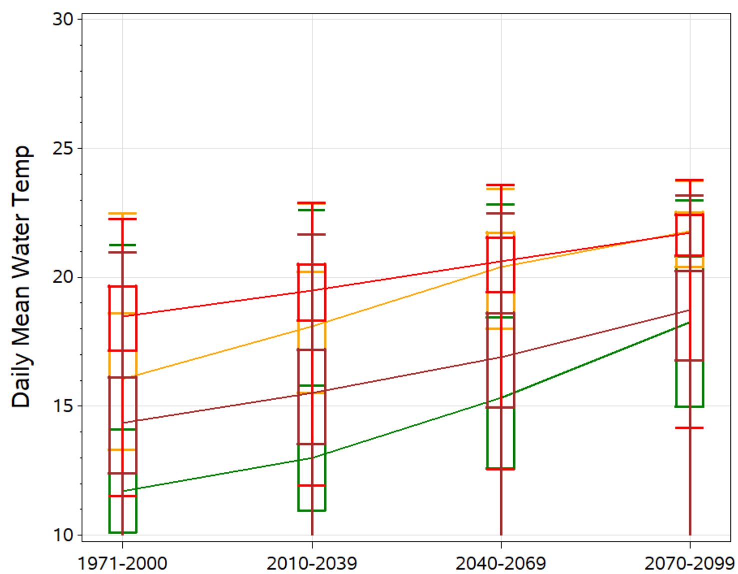

Figure 28. Time trends in Similkameen River summer water temperatures (near Nighthawk, WA), by month, based on an ensemble of CMIP5 Global Climate Models (GCMs) for the 'pessimistic' (RCP8.5) greenhouse gas emission scenario. Box plots indicate median (connected by solid line), quartiles (25th & 75th percentiles), and range (T-whiskers) statistics for 20 GCM runs (Stiff et al. in prep).

The spawning life stage is relatively well understood compared to other life stages for Okanagan Chinook. Nevertheless, the Okanagan Work Group recognizes that improvements can be made to adult monitoring and assessment on both sides of the border. One of the key ways in which advances can be made is to improve operations at the Chief Joseph Hatchery to meet all objectives. A third water source for the hatchery is recommended to alleviate mortality events during broodstock holding. It would also be highly beneficial to the understanding of this population to begin baseline disease and parasite monitoring, on the spawning grounds and at the hatchery, to understand their potential influences on adult Chinook survival to spawning. This information could then be utilized by examining for prevalence of diseases and parasites in years where high pre-spawn mortality is expected. Expression of PSC support for the continuation and full development of a bilateral supplementation program would be useful for efforts to improve the escapement estimates and understanding of this life stage on both side of the border. The persistence of this population at levels that continue to allow harvest demonstrates that there is value in understanding and improving the assessment of this stock.

3.7 Vulnerability to Climate Change

The Okanagan watershed is a low gradient system with a large number of lakes, making it more susceptible to increased stream temperatures as a result of climate change than many other tributary watersheds in the upper Columbia basin, even without the extensive habitat alterations in the Canadian portion. The thermal barrier in the Okanagan is more pronounced than for any other tributary to the Columbia River in the region and it already has major effects on run timing into the watershed. Habitat alterations have increased the risk of increased stream temperatures and altered the hydrograph which increase the risk of winter flooding and associated scouring and late summer low flows. Altered thermal regimes often result in ecological mismatches in aquatic ecosystems, such as fry emergence occurring before food resources are adequate. Increased summer temperatures will result in more favorable environmental conditions for non-native piscine predators in the watershed, as well as in the mainstem Columbia, resulting in increased predation rates on juvenile Chinook unless control efforts can be increased. In the marine environment, summer Chinook are considered 'far-north migrators' typically migrating into the Gulf of Alaska to take advantage of the rich waters to grow and feed. Northern latitudes such as the Gulf of Alaska are expected to experience increased frequency of marine heat waves which alter the distribution of summer Chinook and the abundance, distribution, and composition of the prey assemblages they feed on. All of these changes are likely to result in decreased survival rates and productivity of Okanagan summer Chinook.

Restoring the historic geographic distribution of this stock in Canada and improving their abundance on both sides of the border will increase their climate resilience and may also benefit Chinook management more broadly as this population already has adapted to warmer water conditions than other populations in the upper Columbia.

3.8 Life Cycle Model

Life cycle models for salmon are useful tools for predicting future trajectories of populations and their responses to management interventions and climate change. They incorporate information on abundance and demographic parameters (e.g., survival, reproduction, movement) from multiple life-stages, and can account for relationships between factors that are under management control (e.g., streamflow, sediment, harvest, hatcheries). Having modeled relationships between factors that are under management control and demographic parameters is key to being able to predict the population-level consequences of alternative management strategies. It can also be a valuable tool to represent relationships between factors that may partially be under management control and demographic parameters, such as river temperature and discharge, to model future climate change scenarios and evaluate various mitigation options (e.g., dam operation, changing water extraction point sources, cold water lake siphons, etc.).

At least two life-cycle models currently exist for the Okanagan River summer Chinook salmon population. One is a simple stock-recruitment model presented at the Baseline Assessment workshop on April 21, 2022, which considers the recruitment of the mature cohort as a function of the parental spawner abundance. The second is an Ecosystem Diagnosis and Treatment (EDT; Blair et al. 2008) model also presented at the Baseline Assessment workshop. The EDT model calculates life-stage survival rates within distinct freshwater habitat reaches as a function of habitat conditions within individual reaches. This model estimates population-level survival based on the habitat reaches used by Chinook expressing different life history pathways and the proportion of fish following each pathway. Finally, EDT estimates adult recruitment based on estimates of survival rates after fish leave the Okanagan River Basin. Both models have strengths and weaknesses.

The simpler spawner-recruit model is easy to update with new data, easy to understand, and is well-grounded in biological data on population productivity, whereas the EDT model is more complex, which makes it more challenging to understand, ground-truth and update with new information. EDT is also less informed by biological data on empirical population productivity. However, the EDT model explicitly represents linkages between habitat conditions (i.e., quantity and quality) and life-stage survival rates, and the population responses to habitat restoration in particular areas. It is therefore a valuable tool for translating different types of habitat management actions in different locations into effects on population productivity and abundance.

The EDT model contains relationships between habitat conditions and demographic parameters, many of which were developed based on studies of other populations. As work is conducted to evaluate life-stage demographic parameters (e.g., survival, movement, capacity) for summer Chinook in the Okanagan River Basin, efforts should be made to establish relationships between environmental conditions that are under management control (e.g., fine-sediment input, streamflow, water temperature) and demographic parameters at the population or reach scale. These relationships can replace those currently being used within EDT and could also be used to evaluate management strategies using other models.

The EDT model also incorporates information about the proportion of the population that use different habitat areas at different life stages, and some of this is based on studies from outside the basin. As more data are collected to inform habitat use within the Okanagan Basin (e.g., redd surveys, snorkel surveys, and juvenile sampling), that information should be used to refine the EDT model and to evaluate the population responses to actions in particular areas using other models.

The EDT model is proprietarily owned by the consulting firm ICF, Inc. and updates must be completed by consultants at ICF, Inc. Funding for consultant time is required to make updates to the EDT model as new empirical information becomes available.

Both models meet a specific purpose for fish management in the Okanagan, but neither explicitly addresses some important information gaps that are relevant to recovery of Chinook in the Okanagan. The recovery effort would benefit from a predictive tool that allows managers to identify life-stage specific survival bottlenecks and to understand how those bottlenecks may affect adult returns. A new life-stage-structured population model for Okanagan summer Chinook could be developed by following the general structure of the existing model for spring Chinook in the Wenatchee River Basin presented at the Baseline Assessment Workshop. To the extent that data on abundance by life-stage and survival are available, the development of this model would provide an opportunity to evaluate where in the life cycle the population experiences density-dependent regulation, and to learn about life-stage demographic parameters. A stepwise approach would be appropriate for the development of such a model, which might involve first refining the existing spawner-recruit model. Complexity could then be added by splitting the life cycle into multiple life stages, with the structure of the model following the data available to inform demographic parameters at different life stages. This approach could be particularly useful for understanding the magnitude of life-stage specific bottlenecks for the Canadian portion of the population.

The OWG recommends that the findings on relationships between factors that are under management control and demographic parameters during distinct life stages as described in previous sections be synthesized. This information can be used in combination with life cycle models to predict the outcomes of alternative management strategies, providing information to decision makers about how best to allocate resources for management.

We also suggest that managers consider whether to incorporate support for data acquisition and hypothesis testing into their consideration of alternative management strategies. Life cycle models could be used to simulate the effects of collecting different kinds of data on reducing uncertainties about the outcomes of alternative actions, to inform the allocation of resources toward different kinds of research and monitoring.

Existing population dynamics and life cycle models for Okanagan Summer Chinook should be refined and updated. For example, natural origin recruitment can be estimated from recent unmarked, natural origin escapement data and new CWT-based exploitation rate data, using new methods recommended by the PSC CYER work group, to represent mark selective fishery impacts on unmarked, natural origin fish. New stock recruitment models, such as those representing environmental variation (e.g., smolt-age 3 survival) and the influence of hatchery origin fish spawning in the natural environment, can be evaluated for their performance to identify the best performing model that represents the Okanagan Chinook population dynamics. Building upon the existing EDT model would leverage considerable efforts that have already been put into parameterizing that model but requires support from the consulting firm ICF, Inc. We suggest that the spawner-recruit models be updated with new information and methods. The model can be modified to simulate the outcomes of management strategies and mitigation measures as information becomes available to represent life-stage demographic rates and habitat use. These models can develop more accurate productivity time series and escapement goals for fisheries management, stocks assessment, and planning rebuilding activities and mitigations. With this development, important questions can be investigated, such as what is the productivity of this stock relative to others with similar life-history characteristics? Knowledge gained from this investigation can help inform rebuilding strategies and inform realistic goals based on what is known from other healthy productive populations.

4. RECOMMENDATIONS

The Okanagan summer Chinook historically spawned through the Okanagan River in Canada and the U.S. As such, they are a shared resource. However, despite considerable human development activities in both countries, the portion of the population in the U.S. has been relatively abundant and remarkably productive, while the portion in Canada has been depressed. Improving the historic geographic distribution of this stock in Canada and improving the abundance on both sides of the border will increase the resilience of these culturally, ecologically, and commercially important Chinook salmon in the face of a changing climate. The OWG was created by the PSC as a bilateral forum 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 bilateral coordination and cooperation provided by the OWG has been successful to date. We recommend that the OWG continue as a bilateral forum to aid in the development of supplementation, monitoring, and future research programs, and report annually to the Pacific Salmon Commission.

Paragraph 1 of Chapter 3 of the 2019 PST Agreement lays out the Parties' desires for a sustainable, comprehensive, and coordinated Chinook management regime. Specifically, in paragraph 1(d) the PST states that:

> *successful Chinook conservation, restoration, and harvest management depends on a sustained and bilaterally coordinated program of resource protection, restoration, enhancement, and utilization.*

After considering the diverse issues affecting Okanagan summer Chinook throughout their life cycle, the OWG recommends several activities related to conservation, restoration, enhancement, and harvest management. There are multiple knowledge gaps that the OWG recommends research projects for management entities to pursue and specific recommended activities are listed in Appendix B.

The OWG notes the current renegotiation of the Columbia River Treaty (CRT) and suggests the PSC track the progress of this effort, with respect to potential connections with Okanagan Chinook restoration and the success of a joint supplementation program, if the renegotiation process is amenable to tracking. If the PSC sees value in tracking the CRT renegotiation efforts, the OWG could be tasked with recommending options for PSC consideration that could integrate Okanagan restoration efforts with CRT provisions. Based on our current, admittedly limited understanding of the scope of the renegotiations, the primary connection is likely water management in the mainstem Columbia supporting flows that are conducive to successful upstream and downstream passage.

4.1 Conservation

The Okanagan summer Chinook stock complex experiences a myriad of challenges for conservation. One set of challenges involves the substantial difference between the abundances of fish spawning in each country, with the U.S. spawners numbering in the thousands and being relatively more productive than the fish spawning in Canada, which number less than a hundred in recent times. The stock complex supports substantial contributions to coast-wide fisheries from Oregon to Alaska, thus monitoring exploitation rates is necessary to assess progress towards meeting conservation and rebuilding objectives for Okanagan summer Chinook. Further, there are threats to survival at all freshwater life stages in both countries (e.g., chronic habitat degradation, irrigation and hydro-electric dams, predation and effects of river temperature and discharge). With recently provided passage around irrigation dams in Canada, potential removal of the Enloe Dam in the U.S., and considerable habitat restoration efforts in Canada, bilateral coordination by the OWG is essential to facilitate the evaluation of benefits of these restoration activities in terms of conservation and restoration of the stock throughout the Okanagan watershed. Ultimately the goal is a healthy and productive Chinook resource that sustains benefits to the fisheries of both countries. Measures to strengthen the portion of the run that arrives prior to the onset of the thermal barrier are a useful hedge against climate change impacts. The early migrants are likely to experience more favorable Okanagan River temperatures to successfully migrate to Canada and to the cool water refuge in the Similkameen River. Efforts to increase returns to the Canadian portion of the watershed will aid in population recovery in those habitats.

4.2 Restoration

The OWG recommends habitat restoration projects that will increase the quantity, quality and complexity of the salmon habitats in Canada, since these areas are the most degraded relative to historic conditions and relative to U.S. habitats, where the natural Chinook population is currently doing relatively well. Projects focusing on spawning and egg incubation habitats, increasing the quantity of cool water inputs, river channel complexity, and the riparian zone will help to return the parts of the river in Canada to similar conditions found in the U.S. where there are high spawner densities. In the U.S. Okanagan, spawners are most concentrated within 10 km of the outlet of Osoyoos Lake, likely due to the quantity of high-quality spawning gravels and proximity to a cool water refuge in the Similkameen River. Also, historic photos near the outlets of Okanagan and Skaha lakes suggest these areas historically had high quality spawning habitats prior to dam construction and channelization.

High river temperatures observed throughout the Okanagan River emphasize the critical importance of cool water inputs to the survival and upstream migration of adult Chinook to their spawning grounds, and restoration projects that increase the input of cool water to the Okanagan River will be very beneficial to this stock. Cool water inputs are important mitigation for the effects of climate change since the Okanagan River already experiences high temperatures that affect Chinook salmon migration behavior and can contribute to high mortality of fish. ONA Elders have mentioned that putting the river back to a natural state will reconnect it to thermal refuges.

Several potential restoration projects are presented in Appendix B, including both smaller projects such as inlet and outlet culverts that connect side channels behind dikes to the mainstem river (which reduce the risk of entrainment and stranding) and larger projects, such as relocating dikes further back from the stream channel, reintegrating meanders, and the preferred full reconnection of side channel habitats to restore off-channel rearing areas. The necessary modernization of the Okanagan Lake Regulation System provides a key opportunity to alter existing flow regulation structures such as dams, dikes and VDS with fish friendly modifications, and to build in salmon ecosystem restorations into major improvements, such as the redesign of the dike system to accommodate extreme hydrological events consistent with climate change scenarios.

Removal of Enloe Dam, if feasible, presents very substantial opportunities to increase the population size, productivity and climate resilience of Okanagan summer Chinook. Removal could allow Chinook to access about 100 km of relatively intact habitat in this tributary, with stream temperatures that are significantly cooler than mainstem Okanagan temperatures.

4.3 Hatchery enhancement

A bilaterally coordinated Okanagan summer Chinook hatchery enhancement program with a supplementation component is recommended to increase abundance and secondarily to support fisheries in both countries. Bilateral coordination will help to ensure that the scientifically sound enhancement activities in each country will provide mitigation to fisheries from habitat loss or degradation, or improve productivity through the appropriate use of artificial propagation and supplementation techniques. Currently, programs are planned somewhat independently in each country, and nearly all of the ONA kł cp̓əlk̓ stim̓ Hatchery production has been based on the supply of eggs from the U.S. Chief Joseph Hatchery because the abundance of Chinook in Canada has been too low to effectively collect sufficient broodstock there. The U.S. production is aimed at supporting U.S. Okanagan Chinook enhancement objectives as the first priority. Due to issues with Chinook survival at the U.S. hatchery, the supply of eggs to the Canadian hatchery has been unreliable and has varied greatly among years, with too few provided in 2021 (500 eggs) to support Canadian enhancement objectives.

A bilaterally coordinated and cooperative enhancement program is needed to meet objectives and scientific hatchery guidelines for both countries. The OWG recommendations to increase the Canadian hatchery production include: greater broodstock collection efforts of Okanagan origin Chinook, juvenile rearing and adult holding capacity in Canada, use of enhancement strategies that improve homing to the Canadian spawning grounds, a feasibility study for the collection and holding of broodstock near the outlet of Osoyoos Lake in Washington State, and release of non-adipose fin clipped Chinook in Canada with PIT tags to increase returns to Canada while enabling these hatchery-origin fish to be identified during broodstock collections and monitored at spawning grounds throughout the watershed.

4.4 Harvest management

Rebuilding efforts are designed to increase the abundance as well as the productivity of the entire population. Development of a population dynamics model would facilitate the assessment of priority management actions to achieve those objectives. If a model is developed, it should be on observational escapement (by age) and CWT-based exploitation rate data. The OWG recommends using the most suitable CWT-based method developed by the PSC CYER Work Group, when available, to represent the harvest impacts on natural origin fish, and ultimately to estimate pre-fishery recruitment and stock productivity. Additional potential uses of population dynamics model include:

- development of an estimate of the spawning escapement that would achieve maximum sustained yield,
- a baseline assessment of current productivity and capacity against which to measure the benefits of future restoration activities,
- development and application of a life-cycle model to help identify and prioritize restoration activities that will improve the Chinook production in Canadian and U.S. reaches of the Okanagan River and tributaries, and
- assistance with planning supplementation activities for rebuilding objectives and genetic targets for enhanced contributions of Okanagan Chinook.

Implementation of a bilateral supplementation program will entail establishment of genetic management objectives, and development of strategies to achieve them. Some of the fisheries that currently affect this population in the Okanagan River and the mainstem Columbia are mark selective in order to meet the hatchery broodstock and population conservation objectives. Continued use of mark selective fisheries will remain important for future harvest management actions, as will development of other strategies.

4.5 Recommendations for the Pacific Salmon Commission bodies

The OWG provides the following specific recommendations for the Commission and its bodies to further contribute to the successful conservation, restoration and harvest management of Okanagan summer Chinook.

Commission:

1. Maintain the OWG as a bilateral forum to exchange information to facilitate the restoration of healthy Okanagan summer Chinook.
2. Encourage the development of funding proposals to address report recommendations by providing the report and a cover letter from the Commission to appropriate management entities.

OWG:

1. Help facilitate a bilateral supplementation program to mitigate for the effects of poor egg to fry survival until abundance and distribution are rebuilt. (short-term)
2. Provide assistance to help ensure the kł cp̓əlk̓ stim̓ Hatchery receives sufficient eggs for stock rebuilding and the stock assessment monitoring program by improving the Chief Joseph Hatchery, examining alternative broodstock holding options, and improved broodstock collection. (short-term)
3. Improve the coordination of the collection of data from monitoring programs on the spawning grounds and in the hatcheries. For example, examine marked and unmarked

Chinook for PIT tags to inform decisions about removing live fish from the river for hatchery purposes and to improve the data used for stock assessments (e.g., survival and escapement estimation). (short-term)

4. Develop stock-recruitment models based on escapement (by age and origin), survival (e.g., Columbia River, smolt-age 3, etc.), and coded-wire tag-based exploitation rate data, and then estimate escapement objectives to support harvest management (e.g., escapement to provide optimal production (e.g., S_{MSY}) and limit reference points). (short-term)
5. Compare the productivity of Okanagan summer Chinook relative to other stocks with similar life history characteristics. Examine multiple attributes, including brood year exploitation, smolt to adult survival, and productivity (density-dependent and density-independent components). (short-term)
6. Refine existing life cycle models, or develop new models, to incorporate available information synthesized in this report to help predict the outcomes of alternative management strategies, providing information to decision makers (e.g., simulate the effects of collecting different kinds of data). (medium-term)
7. Update and refine the Chinook population dynamics models, by adding complexity to represent life stage demographic rates and habitat use. (medium-term)

CTC:

1. Apply the methods recommended by the PSC CYER Work Group to generate CWT-based exploitation rates that represent the impacts of mark selective fisheries on unclipped Okanagan Chinook. (short-term)
2. Task the Chinook Technical Committee to modify the CWT ERA tools to accommodate situations for stocks that use inter-dam loss information and are in a similar situation as the SMK indicator stock. For SMK, all estimated CWTs upstream of Wells Dam were included as escapement for the ERA for the IDL, but then the fishery impacts were redistributed from escapement to the terminal fisheries as a step outside of the ERA to generate the mortality distribution tables by the OWG. (short- to medium-term)

Southern Endowment Fund:

The OWG recommends that the Southern Endowment Fund consider restoration projects in the Okanagan in future funding cycles. Examples of projects that could be considered for the Southern Fund are listed in Appendix B.

5. ACKNOWLEDGEMENTS

We gratefully acknowledge all of the workshop participants who contributed their knowledge and insight that helped shape this final synthesis report. A list of people who participated in the workshops can be found below (

Table 14). We would also like to acknowledge Jessica Gill and Caroline Graham for their coordination efforts and support in producing this report.

*Table 14. A list of workshop participants and their affiliations. 'X' denotes participation in a workshop and * denotes that the individual provided a presentation in the workshop.*

Name	Affiliation	Escapement Workshop	Northern Pike Workshop	Survival Workshop	Supplementation Workshop	Baseline Assessment Workshop
Amy Duncan	Okanagan Nation Alliance		X			
Andrea Pearl	Confederated Colville Tribes	X			X*	X*
Andrew Murdoch	Washington Department of Fish and Wildlife	X		X		X*
Antonio Velez-Espino	Fisheries and Oceans Canada	X				
Athena Ogden	Fisheries and Oceans Canada			X*		
Ben Sutherland	Fisheries and Oceans Canada				X*	
Bill Templin	Alaska Department of Fish and Game			X	X	
Bill Tweit	Washington Department of Fish and Wildlife	X	X*	X*	X*	X*
Blaine Parker	Columbia River Intertribal Fish Commission		X			
Brett van Poorten	Simon Fraser University		X			
Brian Heise	Thompson Rivers University		X*			
Brian Riddell	Pacific Salmon Commission Commissioner			X		
Casey Baldwin	Confederated Colville Tribes	X	X	X*	X*	X*
Cassandra Silverio	Ministry of Environment		X			
Catherine Michielsens	Pacific Salmon Commission			X		

Name	Affiliation	Escapement Workshop	Northern Pike Workshop	Survival Workshop	Supplementation Workshop	Baseline Assessment Workshop
Chad Jackson	Washington Department of Fish and Wildlife	X	X		X	
Charles Barr	Oregon Department of Fish and Wildlife			X		
Charles Lee	Washington Department of Fish and Wildlife		X			
Chris Donley	Washington Department of Fish and Wildlife		X			
Chris Fisher	Confederated Colville Tribes			X		X*
Chris Kern	Oregon Department of Fish and Wildlife	X		X		
Christine Mallette	Oregon Department of Fish and Wildlife	X	X	X	X	X
Chuck Parken	Fisheries and Oceans Canada	X	X*	X*	X*	X*
Cody Jacobson	Alaska Department of Fish and Game		X			
Colin McGregor	Fisheries and Oceans Canada				X	
Cory Lagasse	Fisheries and Oceans Canada		X	X*	X	
Dan Stefanovic	Okanagan Nation Alliance				X*	
Dani Evenson	Alaska Department of Fish and Game	X	X	X		X
Daniel Doutaz	Fisheries and Oceans Canada		X			
Dawn Machin	Okanagan Nation Alliance					X*
Dean Allan	Fisheries and Oceans Canada		X		X	

Name	Affiliation	Escapement Workshop	Northern Pike Workshop	Survival Workshop	Supplementation Workshop	Baseline Assessment Workshop
Doug Lofthouse	Fisheries and Oceans Canada				X	
Elinor McGrath	Okanagan Nation Alliance	X*	X	X*	X	X*
Eric Hegerat	Forests, Lands, Natural Resource Operations and Rural Development		X			
Eric Winther	Washington Department of Fish and Wildlife		X			
Evan Smith*	Okanagan Nation Alliance					X*
Flip Pryor	Alaska Department of Fish and Game				X	
Garrett McKinney	Washington Department of Fish and Wildlife				X	
Geoff McMichael	Mainstem Fish Research			X*		
Holly McLellan	Confederated Colville Tribes		X*			
Howard Stiff	Fisheries and Oceans Canada					X*
Howie Wright	Okanagan Nation Alliance			X	X	X
Jeff Fryer	Columbia River Intertribal Fish Commission			X		
Jesse Schultz	Washington Department of Fish and Wildlife		X			
Jessica Gill	Pacific Salmon Commission	X	X	X	X	X
Joe Maroney	Kalispel Tribe		X			
Joel Harding	Fisheries and Oceans Canada				X	
John Artebaum	Confederated Colville Tribes					X*

Name	Affiliation	Escapement Workshop	Northern Pike Workshop	Survival Workshop	Supplementation Workshop	Baseline Assessment Workshop
John Rohrback	Confederated Colville Tribes			X		
Julia McNamara	Recreation and Conservation Office		X			
Justin Bush	Recreation and Conservation Office		X			
Kaitlyn Dionne	Fisheries and Oceans Canada			X	X	X
Kari Alex	Okanagan Nation Alliance			X*		
Keeley Murdoch	Yakima Nation					X*
Kirk Truscott	Confederated Colville Tribes	X			X	
Kory Ryde	Fisheries and Oceans Canada		X	X	X	X
Kristine Dunker	Alaska Department of Fish and Game		X*			
Larissa Chin	Fisheries and Oceans Canada		X			
Lauren Weir	Fisheries and Oceans Canada		X	X		
Mark Sorel	Washington Department of Fish and Wildlife					X*
Martina Beck	Forests, Lands, Natural Resource Operations and Rural Development		X			
Matthew Laramie	United States Geological Survey	X*		X		
Maxine Forrest	Pacific Salmon Commission			X*		
McCoy Oatman	Pacific Salmon Commission Commissioner		X		X	X

Name	Affiliation	Escapement Workshop	Northern Pike Workshop	Survival Workshop	Supplementation Workshop	Baseline Assessment Workshop
Melissa Hack	Fisheries and Oceans Canada				X	
Michael Arbeider	Fisheries and Oceans Canada	X	X			
Michael Tonseth	Washington Department of Fish and Wildlife				X	
Michael Zimmer	Okanagan Nation Alliance		X*			
Mike Matylewich	Columbia River Intertribal Fish Commission	X	X	X	X	X
Nick Bean	Kalispel Tribe		X*			
Norm Johnson	Okanagan Nation Alliance				X	
Parker Bradley	Alaska Department of Fish and Game		X			
Randy Osborne	Washington Department of Fish and Wildlife		X			
Renny Talbot	Fisheries and Oceans Canada		X			
Rick Klumph	Pacific Salmon Commission Commissioner	X	X	X	X	X
Ryan Benson	Okanagan Nation Alliance			X		
Ryan Lothrop	Washington Department of Fish and Wildlife		X*	X	X	X
Sam Pham	Okanagan Nation Alliance					X*
Shawn Narum	Columbia River Intertribal Fish Commission				X	
Skyeler Folks	Okanagan Nation Alliance			X		

Name	Affiliation	Escapement Workshop	Northern Pike Workshop	Survival Workshop	Supplementation Workshop	Baseline Assessment Workshop
Tara White	Forests, Lands, Natural Resource Operations and Rural Development		X			
Thomas Therriault	Fisheries and Oceans Canada		X			
Tommy Garrison	Columbia River Intertribal Fish Commission	X	X	X	X	X
William Gale	U.S. Fish and Wildlife Service				X	

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APPENDIX A: OKANAGAN WORK GROUP TERMS OF REFERENCE

Terms of Reference for Okanagan Chinook Work 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).

Timeline:

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).

APPENDIX B: DETAILED LIST OF POTENTIAL PROJECTS TO AID IN REBUILDING

Report Section	Description	Who	Time Frame
Overarching	Help facilitate a bilateral supplementation program to mitigate for the effects of poor egg to fry survival until abundance and distribution are rebuilt.	PSC OWG Lead, with support from Management Entities	Short-term
Overarching	Support restoration actions that benefit the salmon ecosystem in the Okanagan (e.g., riparian, cold water refugia, gravel recruitment, complexity of stream habitat, water supply, Osoyoos Temperature-Oxygen squeeze).	Management Entities Theme for PSC SEF consideration	Short- to medium-term
Overarching	Support programs in the Okanagan and Columbia River that prevent, monitor, respond to, and suppress the spread of invasive species that are predators on salmon or species and habitat modifications that lead to increased predation on salmon.	Management Entities Theme for PSC SEF consideration	Short- to medium-term
Overarching	Support programs and projects that improve PIT tagging and infrastructure in the Okanagan and Columbia Rivers. This technology supports multiple objectives for Okanagan and other Chinook stocks, and numerous synergies to leverage information were raised repeatedly among all five workshops.	Management Entities Theme for PSC SEF consideration	Short- to medium-term
Overarching	Numerous principal investigators identified the value and potential influence that letters of support from the PSC can have for projects that will benefit Okanagan Chinook. A cover letter providing the report from the Commission to appropriate management entities encouraging the development of funding proposals to address report recommendations.	PSC Commissioners	Short-term
Overarching	The OWG continue as a bilateral forum to exchange ideas and information to facilitate the restoration of healthy Okanagan summer Chinook.	PSC Commissioners	Short- to medium-term
3.1 Egg to fry	Inventory sources of fine sediments entering the Okanagan in Canada and the U.S. and develop mitigation options (e.g., sediment traps on tributaries).	Management Entities	Short-term

Report Section	Description	Who	Time Frame
3.1 Egg to fry	Inventory segments of the Okanagan where gravel recruitment has been reduced due to bank armoring and identify mitigation options (e.g., addition of spawning gravel, spawning platforms).	Management Entities	Short-term
3.1 Egg to fry	Expand the Fish and Water Management Tools for the Okanagan to include extreme river discharge event scenarios that can be anticipated based on climate change model inferences.	Management Entities (Canada)	Medium-term
3.1 Egg to fry	Identify options in Canada and the U.S. to increase the Okanagan flood plain capacity to dissipate high river discharge (e.g., increase the flood plain width by setting back dikes beyond riparian vegetation and dike removal, establish river-flood plain connections to oxbows and paleochannels).	Management Entities	Medium-term
3.1 Egg to fry	Restore river channels to reintegrate meander and increase environmental heterogeneity to increase habitat quantity and quality for the egg to fry life stage.	Management Entities	Medium- to long-term
3.1 Egg to fry	Studies on Okanagan River Chinook-specific egg survival.	Management Entities	Short-term
3.2 Fry to smolt	Improvements to the detection efficiency for PIT tag arrays in Canada and the U.S. to improve survival data quality and to monitor fish migration patterns, timing and duration in the fry to smolt life stage.	Management Entities Theme for PSC SEF consideration	Short-term
3.2.1 Fry to smolt	Fine scale acoustic telemetry and PIT studies to measure survival of parr in various segments of the Okanagan River to identify areas where survival is reduced, and then to identify the mortality mechanisms and mitigation options. For example, survival may be lower in homogenous river segments, lakes with abundant predator populations, etc.	Management Entities Theme for PSC SEF consideration	Short-term
3.2.1 Fry to smolt	Improvements to the quantity and quality of rearing habitat in Canada and the U.S. (e.g., off-channel, side-channel, river meanders, and floodplains restoration and reconnection).	Management Entities	Medium- to long-term

Report Section	Description	Who	Time Frame
3.2.2 Flow control infrastructure	Modernization of the Okanagan Lake Regulation System to make fish friendly modifications to the channel configuration and flow control structures.	Management Entities (Canada)	Medium- to long-term
3.2.2 Flow control infrastructure	Studies on migration delays for juvenile Chinook at dams and vertical drop structures in the Okanagan. For example, high numbers of PIT tags have been detected in the vicinity of Zosel dam which suggest migration delay and vulnerability to predation.	Management Entities Theme for PSC SEF consideration	Short-term
3.2.2 Flow control infrastructure	Improvements to low head dam gates to enable surface-oriented smolts to pass over top of the gates instead of having to pass at the bottom of the gate (e.g., removable spillway weir, replacement of undershot gates with overshot gates, backwatering of vertical drop structures).	Management Entities (Canada)	Short- to medium-term
3.2.2 Flow control infrastructure	Studies on fry entrainment rates and mortality for water diversions and creation of an inventory and debris monitoring program for the outlet gates (where the diverted water returns to the Okanagan River through the dikes).	Management Entities Theme for PSC SEF consideration	Short-term
3.2.2 Flow control infrastructure	Improved connectivity to the main Okanagan River channel for water diversion inlet and outlet culverts, and the full reconnection of side channel habitats as the preferred restoration of off-channel rearing areas.	Management Entities Theme for PSC SEF consideration	Medium-term
3.2.3 Water temperature	Continue the application of PIT tags to Chinook released in Canada and the U.S. to understand juvenile and adult migration timing and survival relative to water temperature and flow.	Management Entities Theme for PSC SEF consideration	Short-term
3.2.3 Water temperature	Restoration of tall riparian vegetation, such as Black Cottonwood, to lower solar heat input.	Management Entities	Medium- to long-term
3.2.3 Water temperature	Conduct feasibility and modern costing for use of hypolimnetic siphons to draw water from deeper, colder areas of one of the mainstem lakes and transport the water to below the outlet dam for release.	Management Entities (Canada)	Short-term

Report Section	Description	Who	Time Frame
3.2.3 Water temperature	Inventory and identify opportunities to change the point of water extraction (e.g., from tributary surface water to ground water), to increase the volume of cool water inputs to the Okanagan River during temperature-sensitive periods.	Management Entities Theme for PSC SEF consideration	Short- to medium-term
3.2.3 Water temperature	The temperature-oxygen squeeze in Osoyoos Lake affects juvenile and adult Chinook. Currently, no cost-feasible options have been identified to mitigate this threat, but new technologies may be identified and warrant consideration.	Management Entities Theme for PSC SEF consideration	Medium- to long-term
3.2.4 Predation	Measures aimed at suppressing invasive predator species (e.g., bass), or the suppression of invasive species that create habitat for ambush predators (e.g., Eurasian water mill foil).	Management Entities	Short- to medium-term
3.2.4 Predation	Develop communication strategies and incentives (e.g., reward programs) to encourage anglers to harvest invasive predator species.	Management Entities	Short- to medium-term
3.2.4 Predation	Develop and apply water management strategies, such as drawing down Vaseux Lake, that can disrupt the nest building and guarding success for bass and reduce their abundance. The seasonal drawdown of Vaseux Lake can reduce the travel time and predation vulnerability for smolts migrating through the lake.	Management Entities (Canada)	Short- to medium-term
3.2.4 Predation	Monitor the abundance of predators to provide a baseline that informs targeted removal and suppression programs.	Management Entities	Short- to medium-term
3.2.4 Predation	Develop an outreach program to inform fishers about the threat of invasive northern pike to help with early detection, notification of costly penalties for spread, and the impacts to fisheries.	Management Entities	Short- to medium-term
3.2.4 Predation	Conduct feasibility studies to use barriers to limit or impede the upstream dispersal of northern pike.	Management Entities Theme for PSC SEF consideration	Short-term

Report Section	Description	Who	Time Frame
3.2.4 Predation	Develop a coordinated approach to monitoring and communication among the management entities in both countries and have a coordinated response plan that can be quickly implemented to suppress northern pike when they are detected downstream of Grand Coulee Dam.	Management Entities	Short- to medium-term
3.3 Smolt emigration	Measures aimed at suppressing invasive predator species (e.g., northern pike, bass), or the suppression of invasive species that create habitat for ambush predator habitat (e.g., Eurasian water milfoil).	Management Entities	Short- to medium-term
3.3 Smolt emigration	Continue to monitor avian predation on juvenile salmonids in the Columbia River Basin and consider population control if the avian predator species can sustain removal and are not subject to treaty provisions regarding protection of migratory birds.	Management Entities (United States) Theme for PSC SEF consideration	Short- to medium-term
3.3.3 Comparison of Survival Estimates	Conduct studies in the Osoyoos Lake area to measure the amount of the apparent mortality rate that arise from predation, residualization, and other sources (e.g., temperature, etc.). Use the inference from these studies to identify and implement mitigation measures to improve the survival of Chinook juveniles through this area.	Management Entities (Canada) Theme for PSC SEF consideration	Short- to medium-term
3.4.2 Inter-dam Loss Estimates	Task the Chinook Technical Committee to modify the CWT ERA tools to accommodate situations for stocks that use inter-dam loss information and are in a similar situation as the Similkameen Summer Yearling (SMK) Okanagan indicator stock. For SMK, all estimated CWTs upstream of Wells Dam were included as escapement for the ERA for the IDL, but then the fishery impacts were redistributed from escapement to the terminal fisheries as a step outside of the ERA to generate the mortality distribution tables by the OWG.	PSC Chinook Technical Committee	Short- to medium-term
3.4.2 Inter-dam Loss Estimates	Estimate the stock-specific inter-dam loss estimates using PIT tag data. Engage the Chinook Technical Committee in the review of this work to potentially improve quality of CWT-based statistics for several Columbia River CWT indicator stocks.	Management Entities Theme for PSC SEF consideration	Short-term

Report Section	Description	Who	Time Frame
3.4.5 Marine fishery sampling rates	Improve the CWT sampling rate for Columbia River net and sport fisheries since these fisheries account for the largest component of the CWT estimated recoveries of Okanagan summer Chinook.	PSC Coded Wire Tagging and Recovery/ Catch and Escapement Indicator Improvement Committee (C2 Committee) Management Entities (United States)	Short-term
3.4.7 Marine insights	Continue the CWT tagging efforts in order to provide a robust time series of exploitation, marine survival and maturation rate information.	Management Entities (United States)	Short- to long-term
3.4.7 Marine insights	Continue to monitor body size at age trends to determine productivity implications and to provide a data set to help with long term investigations into the environmental and other factors that influence the growth rate and size of Okanagan summer Chinook.	Management Entities	Short- to long-term
3.4.7 Marine insights	Apply the methods recommended by the PSC Calendar Year Exploitation Rate work group to generate CWT-based exploitation rates that represent the impacts of mark selective fisheries on unclipped Okanagan Chinook.	PSC OWG and Chinook Technical Committee	Short-term
3.5.1 Migration and holding in the United States	Support feasibility and other studies related to the potential removal of Enloe Dam and re-establish the connectivity of the Similkameen River to enable Chinook Salmon to migrate volitionally, either to seek cold water refugia or for reproduction.	Management Entities (United States)	Short- to medium-term
3.5.2 Migration and holding in Canada	Reconnect the Canadian Okanagan River to natural thermal refuges to create holding habitat.	Management Entities (Canada)	Medium- to long-term
3.5.2 Migration and holding in Canada	Continue to improve fish passage at McIntyre and Skaha Lake Dams.	Management Entities (Canada)	Medium-term

Report Section	Description	Who	Time Frame
3.5.5 Adult migration and holding insights	Improve upstream migration rates by activities such as modifying or removing vertical drop structures and improving passage conditions at the low head dams or by reducing the magnitude and duration of thermal barriers and increasing cold water refugia (e.g., reconnecting cold water tributaries or building cold water siphons).	Management Entities (Canada)	Medium- to long-term
3.5.5 Adult migration and holding insights	Management of fisheries that have the flexibility to consider reducing fishing impacts on the early run timing components of the Okanagan summer Chinook may allow more migrating summer Chinook to experience suitable Okanagan River temperatures prior to the onset of the thermal barrier and may help promote survival and earlier run timing for summer Chinook in Canada.	Management Entities	Medium-term
3.5.5 Adult migration and holding insights	To support Canadian PIT tag studies for the estimation of survival and spawner escapement, it would be helpful for the U.S. management entities to scan broodstock and surplus collections for tags and return the Canadian PIT tagged Chinook to the river to continue their migration.	Management Entities (United States)	Short-term
3.5.5 Adult migration and holding insights	Increase the number of paired PIT arrays and temperature monitoring sites in the Okanagan Basin to improve knowledge about the influence on river temperature on adult migration and holding (e.g., add a PIT array in the Similkameen River upstream of the Okanagan River confluence).	Management Entities Theme for PSC SEF consideration	Short- to medium term
3.5.5 Adult migration and holding insights	Build new, and identify and protect existing, cold water refugia for the survival of migrating and holding Chinook in the temperature sensitive Okanagan River.	Management Entities	Medium- to long-term
3.6 Spawning	Improvements to the Chief Joseph Hatchery, particularly to the water system, would help hatchery programs on both sides of the border and allow for a greater probability of being able to transfer the targeted number of eggs to the ONA.	Management Entities (United States)	Medium-term

Report Section	Description	Who	Time Frame
3.6 Spawning	Provide assistance to help ensure the kł cṗəlk̓ stim̓ hatchery receives sufficient eggs for stock rebuilding and stock assessment monitoring program by improving the Chief Joseph Hatchery, examining alternative broodstock holding options, and improved broodstock collection.	PSC OWG and Management Entities (United States)	Short-term
3.6 Spawning	Improve U.S. Okanagan River Chinook escapement methods to achieve the CTC data standards for escapement indicator stocks (e.g., PIT mark-recapture escapement, genetic mark-recapture study, improved sex ratio methods).	PSC C2 Committee Management Entities (United States)	Short- to medium-term
3.6 Spawning	Improve the coordination of the collection of data from monitoring programs on the spawning grounds and in the hatcheries. For example, examine marked and unmarked Chinook for PIT tags to inform decisions about removing live fish from the river for hatchery purposes and to improve the data used for stock assessments (e.g., survival and escapement estimation).	PSC OWG and Management Entities	Short-term
3.7 Vulnerability to Climate Change	Support scientific monitoring programs in the Okanagan Basin that contribute knowledge about the influence of climate change on Chinook salmon and potential mitigations.	Management Entities	Medium- to long-term
3.8 Life Cycle Model	Refine existing life cycle models or develop new models to incorporate available information synthesized in this report to help predict the outcomes of alternative management strategies, providing information to decision makers (e.g., simulate the effects of collecting different kinds of data).	PSC OWG and Management Entities	Medium-term
3.8 Life Cycle Model	Update and refine the Chinook population dynamics models, by adding complexity to represent life stage demographic rates and habitat use.	PSC OWG and Management Entities	Medium-term
3.8 Life Cycle Model	Develop stock-recruitment models based on escapement (by age and origin), survival (e.g., Columbia River, smolt-age 3, etc.), and coded-wire tag-based exploitation rate data, and then estimate escapement objectives to support harvest management (e.g., escapement to provide optimal production (e.g., S_{MSY}) and limit reference points).	PSC OWG and Management Entities	Short-term

Report Section	Description	Who	Time Frame
3.8 Life Cycle Model	Compare the productivity of Okanagan summer Chinook relative to other stocks with similar life-history characteristics. Examine multiple attributes, including brood year exploitation, smolt-adult survival, and productivity (density-dependent and density-independent components).	PSC OWG	Short-term

APPENDIX C: WORKSHOP SUMMARIES

OKANAGAN CHINOOK ESCAPEMENT PROGRAM WORKSHOP SUMMARY

December 17, 2020

1:00 pm – 4:00 pm PDT (Webinar)

In the Okanagan Chinook Work Group's (OWG) 2021 work plan, the OWG was tasked with hosting a workshop to review the current escapement monitoring programs used in the United States and Canada (Task 6). The main goals of the escapement program workshop are:

(1) Better understanding of both escapement programs
(2) Improved quality of data to support Pacific Salmon Commission (PSC) activities
(3) Summary of advice and feedback for escapement programs
(4) Identify any collaboration opportunities
(5) Identify next steps and recommendations to PSC
(6) Improve information that benefits Okanagan Chinook resource

The OWG approached this workshop by identifying three outcomes associated with Task 6:

A) Review escapement monitoring programs
B) Review escapement monitoring programs relative to the Chinook Technical Committee's data standards for escapement indicator stocks
C) Recommendations to management entities to help achieve data standards

A) Review the current escapement monitoring programs that the management entities use for summer Chinook in the U.S. and Canadian sections of the Okanagan River.

a. Canada:

Elinor McGrath with the Okanagan Nation Alliance (ONA) presented the escapement estimation procedures for the Canadian portion of the Okanagan River. Fish passage improved in 2009 at McIntyre Dam, in 2014 at Skaha Dam, and possibly in 2021 for the Okanagan Dam, opening up new sections of the river to fish spawning and rearing habitats. The Canadian portion of the Okanagan River is highly channelized, and flows are highly controlled using 17 vertical drop structures (VDS). A "natural" and "semi-natural section of the river is used as an escapement index section. These sections and the Penticton Channel are surveyed annually by boat float and river walks for Chinook escapement. At the VDS, observers count all live upstream Chinook. Abundance is estimated using an Area-under-the-curve (AUC) method with a survey life of 7.7 days, informed by literature (Nielson and Green 1981). Actual survey life is unknown but might be biased low due to different application from the literature and applying a new survey life estimate to historical data is challenging. No expansion factor is applied to the estimate the abundance in un-surveyed areas. Ten dead pitch surveys per year are conducted in the index reaches where all Chinook are collected for bio-sampling. Results from the dead pitch survey indicate the AUC abundance estimate are likely biased low (underestimates of actual escapement). Escapement estimates operate under the assumptions that 1) observer efficiency is 100%, 2) survey life is accurate, and 3) spawning occurs in the natural and semi-natural reaches only, and not in the channelized sections that are not surveyed.

b. United States

Matthew Laramie with the U.S. Geological Survey presented escapement methods used in the U.S. portion of the Okanagan River. Escapement surveys run the entire spawning area in the U.S. portion of the river, from Columbia River from mouth of Okanagan upstream to Chief Joseph Dam, Okanagan River from mouth to Zosel Dam at the Canadian border, and the Similkameen River from mouth to Enloe Dam. The river sections are split into eight survey reaches and surveyed over the entire length of the spawning period (late September through early November). Spawning escapement is based on counts of redds multiplied by expanded sex ratios from Wells Dam. Redd counts are conducted using aerial surveys once per week throughout the spawning season with trained observers and using five float surveys throughout the spawning season. Redds are recorded using GPS to ensure aerial surveys do not duplicate float counts. Escapement estimates are based on the assumptions that 1) each female produces one redd, 2) each redd is counted, and 3) the sex ratio at Wells Dam matches ratio on the spawning grounds.

<u>High density redd counts:</u>

ACTION ITEM: Distribute Nicole Trouton (DFO) thesis which used tower surveys to measure survey life in high density spawning areas and could help with verifying the one female per redd assumption

> *Comment*: Sun glare might impact photograph ability to document redd construction, especially in wide rivers such as the Okanagan.

ACTION ITEM: When available, Andrew Murdoch (WDFW) will distribute thesis from a student at Washington State University on use of drone technology to develop model of redd counts on the Wenatchee and Methow Rivers

ACTION ITEM: Examine opportunities to corroborate escapement with an independent estimate using the transgenerational genetic mark recapture (tGMR) method

ACTION ITEM: Distribute paper by Dan Rawding et al describing the tGMR method for the Coweeman Chinook

ACTION ITEM: Distribute copies of Puget Sound reports, Sentinel Stocks Program report, that describe and apply the tGMR method

> *Comment:* Smolt trap catches small fraction of smolts, and sample size analysis would help inform potential to achieve CTC data standards.

B) Review the current escapement estimates relative to the CTC bilateral data standards for Chinook escapement indicator stocks.

The CTC bilateral data standards for Chinook escapement indicator stocks are that the individual estimates of total spawning escapement for a stock should attach a coefficient of variation (CV) of 15% or less and specific estimates of spawning escapement shall be derived with demonstrably asymptotically accurate methods (i.e., methods that produce unbiased estimates). Elinor and Matthew indicated both escapement enumeration projects do not currently meet the CTC data standards for Chinook escapement indicator stocks (i.e., no estimates of precision provided, estimates likely have bias).

C) Recommendations to management entities to help achieve data standards

Elinor discussed a proposal to change the Canadian escapement program intended to achieve the CTC data standards, and the study design report was circulated with the meeting information package. Funding has been requested to implement the PIT tag-based mark recapture escapement study. The study will take advantage of the PIT receiver arrays existing in the Okanagan watershed and releases of PIT tagged hatchery smolt, which has been occurring since 2017. Carcass surveys will continue to occur for bio-sampling and tag recovery, using portable PIT tag receivers and data loggers. Moving to a PIT-based mark recapture program could allow the escapement estimates to meet the CTC data standards if 15,000–18,000 smolts are tagged, based on assuming similar survival and exploitation rates measured on the US component of the stock. This escapement estimation method comes with assumptions that 1) either or both samples (carcass survey and detection at PIT array) are a simple random sample, 2) the population is closed, 3) there is no tag loss during spawning, 4) tagging status of each recovered fish is determined without error, 5) tagging has no effect on the behavior of the fish, and 6) carcass sampling rates do not vary by sex and size.

<u>Tagging fish:</u>
ACTION ITEM: Investigate supplementing PIT numbers for returning adults by tagging fish at Zosel or other downstream dams, follow up with Jeff Fryer (CRITFC) for collaboration.

> *Comment:* Suggestion to not adipose mark the PIT tagged fish to increase tag samples on the spawning grounds. Concern over broodstock PNI management and brood stock collection, which may be mitigated by scanning unmarked Chinook for PIT tags, or by applying CWT and PIT tags and then scanning potential brood stock for CWTs.
>
> *Comment:* Possibly no adult handling facility at Zosel Dam and concerns about tagging in ladder temperatures above 72°F.

ACTION ITEM: Follow up with Andrew Murdoch (WDFW) on hierarchical Bayesian patch occupancy model if tagging at Zosel Dam.
ACTION ITEM: Explore changes to adipose marking with Chief Joseph Hatchery, CCT, and other groups.

> *Comment:* Consider reducing the proportion of releases with an adipose mark for all PIT tagged fish released from the Canadian program because mark selective fisheries will reduce the potential number of PIT tagged fish available for the mark-recapture escapement estimation method.

Comment: With regards to juvenile survival and detection efficiency, Rocky Reach Dam has good PIT detection arrays to get an estimate of survival that is more accurate than tag outputs. NEXT STEP: discuss at the OWG's Survival Workshop later in 2021.

Applications to U.S. Surveys:
ACTION ITEM: Sample size planning figures to achieve PIT tagging targets are in Canadian Okanagan Escapement Study Design report (figures 8–10 on p. 19/20) circulated with pre-workshop materials.

Comment: additional fish would need to be tagged if moving to PIT-based mark recapture for U.S. and the PIT array detection efficiency would need to be verified.

Recommendations:

- Several recommendations were made to improve the existing escapement programs and to consider applying new methods.
    - Examine the feasibility of a transgenerational genetic mark recapture method for the U.S. Okanagan because the main project components are in place (i.e., >20% sampling rate on adult spawners and smolt abundance estimation and sampling program), but collection and analysis of genetic samples would need to be added.
- Treaty funding for improvement of Okanagan Chinook escapement estimates, potentially through Southern Endowment Fund, Catch and Escapement Indicator Improvement program (e.g., national section funding)
- Discuss with Chinook Interface Group in February

ACTION ITEM: Distribute terms of reference to workshop participants, initial PSC report by the OWG, and 2020 OWG report, 2021 OWG work plan.

What was achieved by conducting the workshop?

(1) Better understanding of both escapement programs

Presentations were made about the current escapement programs on both sides of the border. Questions and responses also increased understanding of both programs.

(2) Improved quality of data to support Pacific Salmon Commission (PSC) activities

New professional connections were developed and information was shared about new approaches, and others that are in development. Challenges, issues and limitations were discussed, and potential solutions were shared. Improvements to the Canadian program were initiated with PIT tagging of brood year 2019, with tagged fish anticipated at the spawning grounds in 2022, and improved quality of data likely to occur in 2023 or 24 when there are sufficient numbers of PIT tagged fish for the mark-recapture method. Additional PIT tagged fish will also be available for survival monitoring of downstream migrating juveniles and upstream migrating adults.

(3) Summary of advice and feedback for escapement programs

The presenters and participants engaged in the development of advice and feedback *during the reviews of the escapement programs and proposed new approaches. The meeting summary outlines key comments and action steps.*

(4) Identify any collaboration opportunities

Several collaboration opportunities were identified during the workshop, including:

a) PIT tag-based survival studies for adult and juvenile Chinook that were released in Canada
b) Collaborate with new redd-based escapement estimation methods being developed at the Wenatchee and Methow Rivers via drone studies and model development, and potentially apply the approach to the high redd density area in the Okanagan and Similkameen near Oroville. This reach is challenging to count due to superimposition of redds and high densities.
c) Examine the potential to conduct tagging at Zosel Dam to increase data for Canadian mark-recapture program, and follow up with other investigators applying tags to adults in the Columbia River mainstem
d) Examine potential to apply PIT tag mark-recapture method in US Okanagan and collaborate with other PIT tag studies there, possibly using existing infrastructure.

(5) Identify next steps and recommendations to PSC

See next section.

(6) Improve information that benefits Okanagan Chinook resource

Several constructive suggestions were made to improve the quality of escapement data and to address key uncertainties with programs on both sides of the border. Subsequent improvements to escapement estimation programs to address issues related to the bias and precision of the estimates will improve the quality of other types of monitoring data in the Okanagan

- Chinook spawner abundance data used for stock assessments in Canada and the United States
- Estimation of Chinook salmon productivity (i.e., spawners and recruitment)
- Coded-wire tag statistics for exploitation, survival and maturation rates, estimates of survival of juveniles and adults migrating in the Columbia (including inter-dam loss factors used by the Chinook Technical Committee). The escapement component may be underestimated currently.
- More accurate estimates of the Chinook spawner abundance information used to implement Hatchery Genetic Management Plans (e.g., pNI)

<u>What are the Next Steps?</u>

- Develop list of recommendations for additional investigations and tagging
- Discuss recommendations with CIG/Commissioners for potential suggestions for funding
  - e.g. Chapter 3 Catch and Escapement Indicator Improvement (CEII) program funded via national sections, Southern Endowment Fund (SEF) priority, others

- Circulate Terms and Reference (ToR) and Work Plan to the workshop participants/invitees, as other workshops will happen in 2021 and there is interest in knowing more about them
- PDF presentations to be circulated
- Meeting summary will be circulated.
- OWG PSC tech report link to be circulated

Attendees

Attendee	Country	Affiliation
Andrea Pearl	U.S.	Confederated Colville Tribes
Andrew Murdoch	U.S.	Washington Department of Fish and Wildlife
Antonio Velez-Espino	Canada	Fisheries and Oceans Canada
Bill Tweit	U.S.	Washington Department of Fish and Wildlife
Casey Baldwin	U.S.	Confederated Colville Tribes
Chad Jackson	U.S.	Washington Department of Fish and Wildlife
Chris Kern	U.S.	Oregon Department of Fish and Wildlife
Christine Mallette	U.S.	Oregon Department of Fish and Wildlife
Chuck Parken	Canada	Fisheries and Oceans Canada
Dani Evenson	U.S.	Alaska Department of Fish and Game
Jessica Gill	PSC	Pacific Salmon Commission
Kirk Truscott	U.S.	Confederated Colville Tribes
Michael Arbeider	Canada	Fisheries and Oceans Canada
Mike Matylewich	U.S.	Columbia River Intertribal Fish Commission
Rick Klumph	U.S.	Pacific Salmon Commission Commissioner
Tommy Garrison	U.S.	Columbia River Intertribal Fish Commission
Elinor McGrath	Canada	Okanagan Nation Alliance
Matthew Laramie	U.S.	United States Geological Survey

OKANAGAN CHINOOK NORTHERN PIKE WORKSHOP SUMMARY

April 21, 2021

1:00 pm – 4:00 pm PDT (Webinar)

The Okanagan Chinook Work Group (OWG) was established by the Pacific Salmon Commission (PSC) in 2019 and was charged to coordinate and monitor efforts by both countries to increase the return of Okanagan River Chinook (*Oncorhynchus tshawytscha*) to the Canadian portion of the watershed. Northern pike (*Esox lucius*) have been identified as a very serious potential threat to increasing production of summer Chinook in Canadian waters.

Species Introduction

Northern pike are a species native to the Peace (British Columbia [BC]), Saskatchewan (Alberta), and Missouri (Montana) rivers. Rivers. However, the species has been introduced, often illegally, into the Columbia and Pend Oreille Watersheds above Grand Coulee Dam (Figure 1).

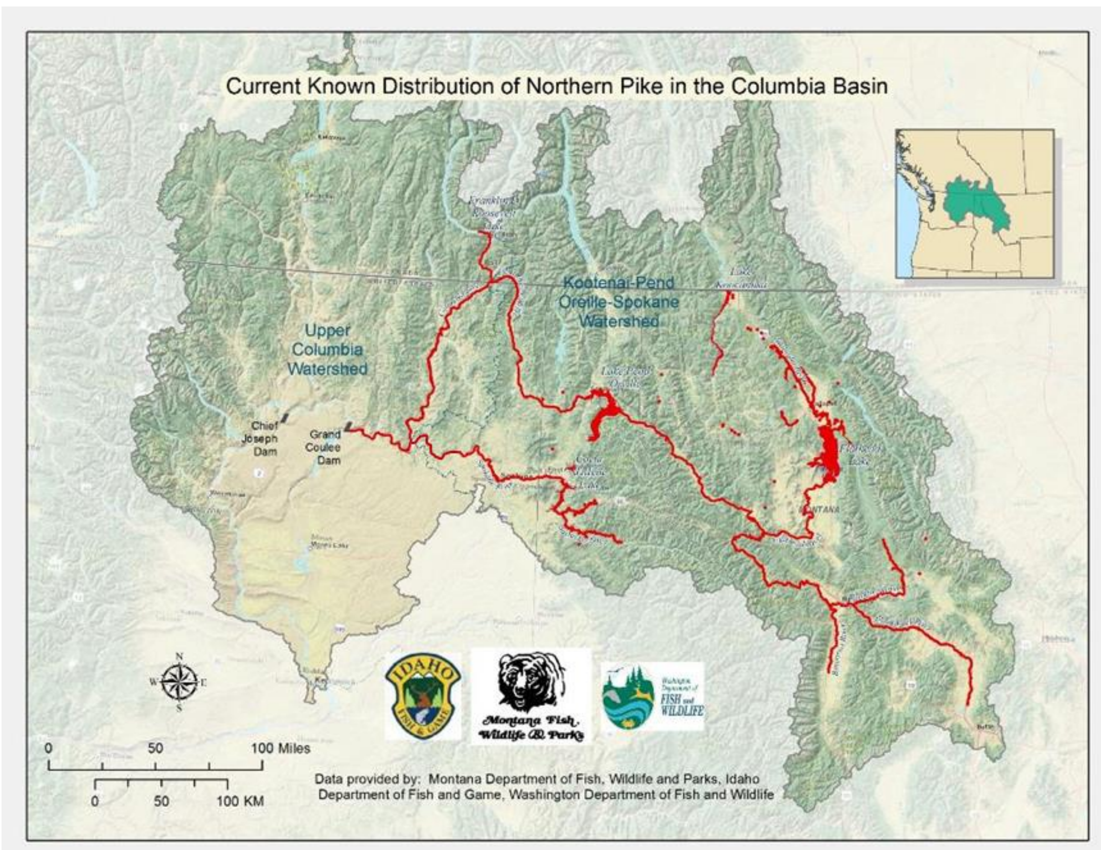

Figure 1. Known distribution of invasive northern pike in the Upper Columbia and Pend Oreille watersheds in 2021.

Females have high fecundity, producing 15,000-60,000 eggs. They are obligate spawners utilizing shallow, sheltered areas with aquatic vegetation, grasses and sedges during the spring freshet when water temperatures reach 8-12°C. Northern pike generally do not migrate great distances, only migrating during the spawning season.

Although they are generalists feeding on a variety of prey, they have been documented to target salmonids (5-100% of diet among many lakes examined by Cathcart et al. 2019) when their ranges overlap.

Programs for removal in the Columbia and Pend Oreille Rivers include angler reward programs, chemical treatment for eradication using rotenone, and netting (i.e., gill, trap, and seine netting).

Issues Related to Northern Pike Introduction

Northern pike were introduced illegally to southcentral Alaska in the 1950s. Since then, Northern pike have expanded to 150 water bodies in the 25,000 square mile Susitna River watershed and are believed to have migrated across Cook Inlet to the Kenai Peninsula. Otolith microchemistry on northern pike from the Kenai Peninsula has identified dispersal through the estuarine environment. Northern pike are a top predator in their native range and coexist with salmon runs. However, in parts of their native ranges, the habitat includes large, deep lakes which allow for habitat segregation and coexistence. In areas of northern pike introduction, the shallow, marshy water bodies have provided exceptionally good habitat for northern pike without providing segregation of rearing habitat and migration corridors for juvenile salmonids.

In Alexander Creek, the introduction of northern pike led to the collapse of a multimillion-dollar salmon fishery, the decline of Chinook from escapements in the 6,000s in the early 1980s to less than 500 in 2008, prompting the listing of the stock as a stock of concern. Due to northern pike suppression efforts in the creek, the Chinook population has increased to over 1,000 in 2019. In smaller lakes, up to 100% loss of salmon occurs after northern pike introduction.

In northeastern Washington, northern pike were detected in 2004 in Box Canyon and Boundary Reservoirs along the Pend Oreille River. After detection, northern pike were studied by the Kalispel Tribe and Washington Department of Fish and Wildlife (WDFW) until 2010 to establish abundance thresholds (reduction targets) and standardize suppression efforts and abundance surveys with gill nets. During the six-year study period, the northern pike population expanded rapidly due to the high-quality northern pike habitat in the two water bodies with shallow, slow-moving water and off-channel sloughs. Northern pike were first observed in Lake Roosevelt in 2014 and the Lake Roosevelt Suppression and Monitoring Plan was developed in 2015 by the Confederated Colville Tribes (CCT), the Spokane Tribe, and WDFW.

Northern pike were first detected in the Kootenay region of southeastern BC in Ha Ha Lake in 2005 and in the Canadian portion of the Columbia River in 2010 below Arrow Lakes. Photo evidence suggests that northern pike may have colonized Christina Lake, but it is unclear if it was a novel excursion or illegal introduction. It is possible for northern pike to pass upstream through the BC Hydro Navigation Locks on the river. This is a major risk that has not been addressed, and there is potential for northern pike to invade upstream. Christina Lake Stewardship Society has commissioned a barrier feasibility study for Christina Creek (*in press*). These areas are good habitat for northern pike, and they are expected to do well once established. The upper Columbia River in the Kinnabasket Reservoir and the free-flowing sections from Donald, through Golden and to Invermere are ideal habitat for northern pike, with many large wetlands and seasonally flooded off-channel oxbows. These areas are very low gradient providing slow-moving habitat, which northern pike will do quite well in.

Current Methods of Removal

The Alaska Department of Fish and Game (ADF&G) has a robust response to address invasive northern pike, which includes four functional areas: outreach, research, suppression, and eradication. Outreach is aimed at increasing awareness of the problems caused by invasive northern pike in southcentral Alaska, establishing penalties for moving northern pike and promoting targeting of northern pike by anglers to control the population. Research has occurred in collaboration with multiple partners and is aimed at understanding the impacts of northern pike invasion and control methods. Research efforts also include eDNA methods to identify water bodies with northern pike detections. Suppression efforts include targeting northern pike with gill nets during the spawning period and in periods of juvenile salmonid outmigration to control for predation. These efforts appear to be working in areas where suppression is the only course of action. Eradication efforts are focused on removing northern pike populations in their entirety using rotenone. These efforts have been successful in 23 waterbodies in southcentral Alaska and have been focused on the Kenai Peninsula in recent years. The Kenai Peninsula project is under the permitting phase with expected application of rotenone in October 2021. If deemed successful, native fish will be returned to the treated lakes in summer 2022. ADF&G operates northern pike suppression and eradication efforts primarily through grant funding of approximately $145,000 USD per year. Eradication projects are funded individually, from $20,000-$500,000.

In northeastern Washington, the first major suppression efforts of northern pike from the Kalispel Tribe and WDFW occurred in Box Canyon Reservoir in 2012 after the pre-suppression survey indicated high relative abundance of northern pike. The suppression efforts aimed for a mean number of northern pike per net as derived from the catch per unit effort (CPUE) abundance survey. From 2012-2020, over 18,000 northern pike were removed from the reservoir with 5,300 gill nets and the CPUE has been below the threshold limit since 2013. In the Boundary Reservoir, suppression efforts began in earnest in 2017. The population has been below the abundance threshold CPUE since 2018, with 420 gill nets removing 600 northern pike. Gill net effort is still required to maintain the population below the abundance threshold, though at reduced levels than the initial suppression efforts.

In the Columbia River below Arrow Lakes, dedicated suppression efforts began in 2014, which included gill net removals and angler incentive programs by both the Okanagan Nation Alliance (ONA) and the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). These efforts have removed 672 northern pike from the Canadian portions of the Columbia and Pend Oreille Rivers. Research efforts have focused on water temperature and growth and suggests that water temperatures above 10°C allow for rapid growth of young-of-year northern pike. The ONA has scheduled high gill net effort for northern pike suppression in 2021 as well as sampling for eDNA in the spring and fall at 13 sites.

In Lake Roosevelt, suppression efforts by CCT, WDFW, and the Spokane Tribe via gillnetting and reward programs occur most of the year, with other netting and fishing operations occurring in the summer and fall. Since 2015, suppression efforts have removed 16,020 northern pike, primarily from the upper half of the reservoir. Angler reward programs have distributed $31,940 (USD) to anglers for northern pike heads ($10/head), using a head recovery program with freezers located at depots through the communities. Suppression programs can be expanded or diverted if northern pike are found in Lake Rufus Woods, the Wells pool, and Okanagan Rivers. Research and monitoring via creel surveys and public outreach occurs throughout the year, while eDNA studies and microchemistry research occurs in the spring and late fall/winter.

Actions to Address Northern Pike Expansion into Okanagan River

Prevention
Discussion Questions
1. How suitable is the Okanagan habitat for northern pike production? How well might suppression work there? In other words, how great is the risk? 2. What are the most important tools that we should rely on for prevention of expansion into the Okanagan? 3. What are the major impediments to successful prevention? Institutional, ecological, system operations, political boundaries, etc.?
Responses
- The Okanagan watershed is highly susceptible to northern pike invasion. It is characterized by low gradient slopes, slow moving back water areas, and has high levels of aquatic plants. The Wells Pool, downstream of Chief Joseph Dam, was identified as a critical pathway for colonization. • Habitat suitability GIS mapping can help with identifying areas to target for netting efforts. • Osoyoos, Vaseux, and the Okanagan River connecting these lakes have considerable shallow areas with aquatic vegetation that are ideal habitat for northern pike. - Prevention is the most effective invasive species management followed by a rapid response. - A transboundary spatial model of likely population extent informed from eDNA, angler reports, and gill net/e-fishing data could inform response and monitoring. This would need coordinated databases but would be the best way to stay on top of the population by understanding where the population frontier is. It should either be linked to regional reporting sites, such as the tool for summarizing Northern Pike Monitoring Data at nwcouncil.org or an integrated transboundary reporting tool could be developed. - Public education efforts (signage, fines) are key to preventing illegal stocking and expansion into non-native territory. • Angler interest in northern pike where they are present is quite high and, in general, anglers are onboard for removal programs in Lake Roosevelt. In other areas, angler opinion is mixed, some supporting northern pike introduction as a desirable fishery, and others opposing it due to their deleterious impacts on native fish. • In Lake Roosevelt, presentations were given to the walleye club and Trout Unlimited to help get the word out and particular efforts were made to reach anglers during walleye and bass tournaments. • A human dimensions study of Canadian and American anglers would help understand how important they are to anglers, and then how likely they would be to move or remove them. - Physical barriers such as the vertical drop structures in place on the Okanagan are unlikely to prevent northern pike from colonizing due to their ability to jump (recorded 1.5m), unless they are modified, and migration access is actively restricted. • Sorting in fish ladders by hand or with the Whoosh system at the McIntyre, Skaha Lake, Okanagan Lake, and Zosel Dams could help with removal and impede the natural dispersal of northern pike upstream.

Action Planning

- Two sources of northern pike invasion: 1) illegal stocking and 2) natural movement and dispersal, with some seasonal restrictions at fishways and barriers.
- Illegal stocking can be addressed through a public awareness campaigns targeting "bucket biologists" and anglers.
- The barrier feasibility study at Christina Lake, BC may provide information to inform the feasibility of barriers in the Okanagan.
- Public awareness can be done through government, invasive species, and fishermen groups, alongside a social media strategy.
  - Having a consistent, coordinated message is key. Recommend Invasive Species Council of British Columbia, Washington Invasive Species Council, and state and provincial fisheries agencies develop harmonized transboundary messaging.
  - BC FLNRORD has a phone reporting app for invasive species as do several Washington agencies including the Invasive Species Council and WDFW. Recommend all parties discuss a notification process and structure to share transboundary northern pike reports.
  - Communication with fishing license purchasers and follow-up electronically.
  - Creel survey interviewers are a great resource to help get information out to the public
  - Information on northern pike could be increased in the regulation booklets, social media and other communication tools used by fisheries agencies.
  - Target social media influencers to spread awareness. Fisheries management agencies are recommended to develop common talking points for communications and messaging.

Early Detection Monitoring

Discussion Questions

1. Is our current program adequate for detecting their presence in the Okanagan?
   - If not, what should be added and how soon?

Responses

- Increase eDNA sampling in the Okanagan River for early detection and utilize eDNA studies already in place for other species (e.g., invasive zebra mussels).
  - If an eDNA sample returns a positive identification for northern pike, have a strategy in place to determine if northern pike are physically present in the system.
  - eDNA can pick up trace amounts of DNA, even when a carcass is dumped in a watershed without northern pike or from DNA retained in sediment after northern pike removal. Need to confirm northern pike are in the system when a new positive sample is identified.
- For northern pike confirmation, boat electrofishing, fyke nets, and seine nets are easier to use when endangered and other species of concern are present. Gillnets are effective but not the only tool for suppression.
- Mark-recapture studies on northern pike have been limited due to funding limitations

and their occurrence in large systems. ONA conducted mark-recapture studies to establish baseline population levels, but they are no longer comfortable releasing northern pike after capture.
Action Planning
- Identification of prime northern pike habitat in the Okanagan River could help targeted suppression efforts and develop a study design for continued suppression. • A phased approach of gillnetting downstream and at the mouth of the Okanagan could be part of the implementation and management plan. • When gillnetting is not an option (concerns about listed species, bycatch), consider mesh size, net tending, or other fishing techniques (fyke nets, electrofishing). - Coordinate eDNA sampling among agencies conducting sampling, but do not rely solely on eDNA methods for a positive sample. • Grant County Public Utilities Department (PUD), Douglas County PUD, WDFW, CCT all have eDNA sampling. • Recommendation to convene a transboundary eDNA coordination call, to coordinate eDNA sampling among agencies, in addition to determine exactly how eDNA sampling should be increased and by whom. - Ensure consistent language when anglers encounter northern pike and who to contact when a northern pike is detected. • Retain northern pike and report to BC or WDFW when outside native range. WDFW - Phone: 1-360-902-2700 - Email: fishpgm@dfw.wa.gov - Mobile App: Create a report at invasivespecies.wa.gov or use ‘WA Invasives’ app on iOS or Android • BC - Phone: 1-250-305-1003 - Email: info@bcinvasives.ca - Mobile App: Create a report at bcinvasives.ca or use ‘Report Invasives BC’ app on iOS or Android

Response Preparedness
Discussion Questions

Planning
1. Are existing plans adequate for preparation?
   - If not, how valuable would it be to have an Okanagan specific plan? Which parties should be involved? Are there existing plans that might provide a good model if an Okanagan specific plan would be useful.
2. Should a response plan have an eradication objective or immediate suppression?

Permits
1. Is there an existing inventory of the Canadian and U.S. permits that would be needed to conduct a response?
2. Are there likely coordinators to facilitate permitting?

Resources
1. How do we begin planning for resources, knowing that we don't have adequate resources now?
2. Should we worry that resources might come at a cost to existing suppression programs?

Responses

- Valuable to have an Okanagan specific management plan in place with clear points of contact and a notification plan when detections happen. In early days of detection, an eradication objective to the management plan is ideal.
- Communication is key among parties involved.
- CCT has a broad permit for non-native predator control but would need to add more details to expand to the Okanagan River. Permitting by the U.S. Fish and Wildlife Service and National Marine Fisheries Service is challenging due to endangered species constraints.
- ADF&G applied for permits for eradication efforts (rotenone application) through the Alaska Department of Environmental Conservation (pesticide use and public comment), National Environmental Policy Act (environmental assessment and public comment), Alaska Department of Natural Resources (land use permit), and ADF&G (fish transport permit).
- WDFW has two National Pollutant Discharge Elimination System (NPDES) permits (General and Aquatic Invasive Species [AIS]) to treat waters of the state with rotenone through the U.S. Environmental Protection Agency. Application in the watershed would be for lakes/ponds and some streams with surface water connections to the Columbia River or tributaries. The AIS permit is best for rapid response. The general permit takes about a year from start to finish.
- BC FLNRORD would supply permits for gill net suppression work, but a federal permit would be required for eradication with rotenone.
- Funding was reallocated from other projects as northern pike suppression was prioritized after understanding that northern pike introduction would cause more costly problems if not dealt with.
- Adequate and sustainably funded suppression programs upstream of the Okanagan River are great prevention and protection for the basin and must be maintained.

Action Planning

- Douglas County PUD and CCT have plans in place for northern pike suppression and necessary permits.
- Reallocate funding as needed to deal with the problem. The funding response can be part of the Response Plans for northern pike Invasion.
- Have partnerships to facilitate cross border work and gain potential funding avenues.
- When bringing to decision makers, consider how the current situation represents a new level of risk (e.g., first time northern pike has been seen in Okanagan).
    - Elevate northern pike as prohibited species in BC for more funding.
    - In Washington, northern pike are Prohibited Level 1 species, allowing for a request for emergency measures from the Governor. Recommendation to develop template director's findings that contain an evaluation of the effect of the emergency measures on environmental factors such as fish listed under the endangered species act, economic factors such as public and private access, human health factors such as water quality, or well-being factors such as cultural resources.
    - Very hard to be preventative in nature but rapidly deployed management intervention can change the outcome given the risk to salmon.

Key Findings and Recommendations
Impacts ○ Northern pike are a serious threat to survival and abundance to Chinook in the Okanagan River from the mouth upstream. If northern pike colonize below Chief Joseph Dam in the mainstem of the Columbia River, long term suppression efforts will be necessary and costly. ○ Northern pike pose a threat to other Columbia River salmonids and the fisheries that are dependent on them.
Prevention ○ Northern pike may arrive in the Okanagan River via dispersal and illegal stocking.   ○ Dispersal may be controllable at existing fishways or dams in the Okanagan River, and feasibility planning and testing may be needed to identify suitable approaches to limit upstream and downstream dispersal. ○ Public awareness and outreach programs, disincentive approaches, enforcement, and best practices can help reduce the likelihood of an introduction from illegal stocking. ○ Recommend Invasive Species Council of British Columbia, Washington Invasive Species Council, Tribal, First Nations, state, and provincial fisheries agencies develop harmonized transboundary messaging.
Early Detection Monitoring ○ A coordinated approach to early detection monitoring is needed to collect and disseminate information in order to enable a rapid response when northern pike are found in the Okanagan. Recommend increasing the scope of https://pike.nwcouncil.org/monitoring/ tool to include Canadian waters and management in addition to including eDNA and other monitoring types. ○ A coordinated communication plan is needed among the Tribal and First Nations fishery managers, the state and provincial fisheries agencies, and invasive species councils.

- The current eDNA monitoring programs (https://pike.nwcouncil.org/monitoring/) can be reviewed to identify which species are being monitored and map locations, map out the potential habitat and distribution for northern pike and overlay that with the current eDNA monitoring for northern pike, and then identify gaps and prioritize them to facilitate improving the early detection network. - Public outreach can be used to increase the awareness of the existing tools to report AIS.
Response Preparedness - A bilateral response plan will be invaluable for agencies to prepare for and coordinate actions for the suppression, eradication and to restrict the spread of northern pike in the Okanagan. The plan should include approaches for communication, media messaging, and potential funding opportunities. The plan should identify the permits necessary for suppression, to limit dispersal, and for eradication. The plan may involve a gap analysis component to acquire information that would be helpful to improve the response plan.

Next Steps
Discuss workshop findings and recommendations with the Commission for their feedback and advice.

Workshop Materials	
Attachment Number	**Title**
1	OWG Northern Pike Workshop Agenda.pdf
2	PSC OWG Northern Pike Workshop.pptx
3	Ecology of Invasive Northern Pike_Heise.pptx
3a	Columbia River Northern Pike_Doutaz 2014.pdf
4	Invasive Northern Pike History, Impacts and Control in Upper Cook Inlet_Dunker.pptx
4a	Cathcart et al. 2019.pdf
4b	Sepulveda et al. 2014.pdf
5	Pend Oreille River Northern Pike Suppression_Bean.pptx
6	Northern Pike in the Canadian Columbia Basin_Zimmer.pdf
6a	Harvey 2009.pdf
6b	Duncan et al. 2019.pdf
6c	Columbia Basin Invasive Northern Pike Suppression and Monitoring_ONA.pdf
7	Lake Roosevelt Northern Pike Suppression and Monitoring Program_McLellan.pptx
7a	Lake Roosevelt Northern Pike Suppression Plan 2018-2022 Final.pdf

Potential Partnerships (outside of agencies on call)

- Christina Lake Stewardship Society
- Douglas County PUD
- Grant County PUD
- BC Hydro
- Upper Columbia Salmon Recovery Board
    - Board of Directors
    - Regional Technical Team
    - Education and Outreach
- Northwest Power and Conservation Council
- Invasive Species Council of British Columbia
- Regional British Columbia Invasive Species Society – Our Networks - Invasive Species Council of British Columbia (bcinvasives.ca)

Documents and Links

- Lake Roosevelt Suppression and Monitoring Plan (attachment 7a)
- Christina Lake Stewardship Society barrier feasibility study (Suzanne Vincent, Coordinator)
- Okanagan Nation Alliance Pike Suppression (attachment 6c)
- Upper Columbia United Tribes Northern Pike Technical Team

Acknowledgements

Julia McNamara, Justin Bush, and Council Chair Joe Maroney of the Washington Invasive Species Council provided invaluable assistance in organizing the workshop. Our panelists (Dr. Brian Heise, Kristine Dunker, Nick Bean, Holly McLellan, Michael Zimmer) provided very useful information.

Attendees

Attendee	Country	Affiliation
Dean Allan	Canada	Fisheries and Oceans Canada
Michael Arbeider	Canada	Fisheries and Oceans Canada
Casey Baldwin	U.S.	Confederated Colville Tribes
Nick Bean*	U.S.	Kalispel Tribe
Martina Beck	Canada	Forests, Lands, Natural Resource Operations and Rural Development
Parker Bradley	U.S.	Alaska Department of Fish and Game
Justin Bush	U.S.	Recreation and Conservation Office
Larissa Chin	Canada	Fisheries and Oceans Canada
Chris Donley	U.S.	Washington Department of Fish and Wildlife
Daniel Doutaz	Canada	Fisheries and Oceans Canada

Attendee	Country	Affiliation
Amy Duncan	Canada	Okanagan Nation Alliance
Kristine Dunker*	U.S.	Alaska Department of Fish and Game
Dani Evenson	U.S.	Alaska Department of Fish and Game
Tommy Garrison	U.S.	Columbia River Intertribal Fish Commission
Jessica Gill		Pacific Salmon Commission
Eric Hegerat	U.S.	Forests, Lands, Natural Resource Operations and Rural Development
Brian Heise*	Canada	Thompson Rivers University
Chad Jackson	U.S.	Washington Department of Fish and Wildlife
Cody Jacobson	U.S.	Alaska Department of Fish and Game
Rick Klumph	U.S.	Pacific Salmon Commission Commissioner
Cory Lagasse	Canada	Fisheries and Oceans Canada
Charles Lee	U.S.	Washington Department of Fish and Wildlife
Ryan Lothrop*	U.S.	Washington Department of Fish and Wildlife
Christine Mallette	U.S.	Oregon Department of Fish and Wildlife
Joe Maroney	U.S.	Kalispel Tribe
Mike Matylewich	U.S.	Columbia River Intertribal Fish Commission
Elinor McGrath	Canada	Okanagan Nation Alliance
Holly McLellan*	U.S.	Confederated Colville Tribes
Julia McNamara	U.S.	Recreation and Conservation Office
McCoy Oatman	U.S.	Pacific Salmon Commission Commissioner
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Chuck Parken*	Canada	Fisheries and Oceans Canada
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Kory Ryde	Canada	Fisheries and Oceans Canada
Jesse Schultz	U.S.	Washington Department of Fish and Wildlife
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Renny Talbot	Canada	Fisheries and Oceans Canada
Thomas Therriault	Canada	Fisheries and Oceans Canada

Attendee	Country	Affiliation
Bill Tweit*	U.S.	Washington Department of Fish and Wildlife
Brett van Poorten	Canada	Simon Fraser University
Lauren Weir	Canada	Fisheries and Oceans Canada
Tara White	Canada	Forests, Lands, Natural Resource Operations and Rural Development
Eric Winther	U.S.	Washington Department of Fish and Wildlife
Michael Zimmer*	Canada	Okanagan Nation Alliance

*Denotes a presenter

OKANAGAN CHINOOK SURVIVAL WORKSHOP SUMMARY

July 14, 2021

1:00 pm – 5:30 pm PDT (Webinar)

The Okanagan Chinook Work Group (OWG) was established by the Pacific Salmon Commission (PSC) in 2019 and was charged to coordinate and monitor efforts by both countries to increase the return of Okanagan River Chinook (*Oncorhynchus tshawytscha*) to the Canadian portion of the watershed. This workshop was aimed at identifying bottlenecks to survival of Canadian Okanagan Chinook. The workshop participants reviewed different factors affecting survival at each of the following life stages: egg incubation, fry rearing and smolt emigration, and adult return migration. Participants ranked factors according to influence on survival at each life stage. Results of the weighting exercise can be found on page 111.

Key Findings and Recommendations
o Habitat restoration should be the highest priority to restore the Canadian Okanagan to as natural of a state as practical   o e.g., removal/modification of the antiquated VDS structures, reconnection with natural river channel, riparian restoration
o Several key scientific research areas were identified to gain a better understanding of the mechanisms affecting juvenile and adult Chinook survival in the Okanagan.   o e.g., studies on predation, sedimentation, and migration timing and delays
o Support the planning for potential climate change impacts on the Canadian portion of the river. The confined channel is insufficient to contain the volume of water expected under future climate change conditions. Water management will have to reconfigure the channel to accommodate larger water volumes, and this opportunity can be leveraged to reconfigure the channelized sections and re-establish the ecological processes that lead to a productive river system for Chinook Salmon.

Background
Okanagan summer Chinook in the U.S. and Canada are part of the same population, but show different escapement patterns. Escapement increased during the early 2000s in the U.S. portion of the Okanagan River, but remained low in Canada. Canadian Chinook spawn in the mainstem Okanagan River between Osoyoos Lake north to the outlet of Okanagan Lake (Figure 1). Spawning mainly occurs in an 8 km section of natural or semi-natural stream channel immediately north of Oliver, BC. The remainder of the Canadian Okanagan River is heavily channelized with relatively little Chinook spawning activity. In the channelized section from Oliver to Osoyoos Lake, there are 13 Vertical Drop Structures (VDS), which are engineered low-head concrete weirs, and 4 additional VDS between Vaseux and Skaha Lakes, which regulate channel gradient. The channelized sections are confined, and they have very few accessible off-channel rearing habitats (e.g., floodplains or side channels), although there are extensive wetlands at the north end of Osoyoos Lake where the historic river channel was. Fish navigate additional migration impediments at Skaha Lake Dam, McIntyre Dam, and Zosel Dam into the U.S. Okanagan River and nine Columbia River mainstem dams.

The summer Chinook stock is primarily of ocean-type life history and juveniles migrate to the ocean within a few months of emergence in the spring following hatching. The Okanagan Nation Alliance (ONA) has been raising Chinook eggs at the *kł cp̓əlk̓ stim̓* Hatchery in Penticton since 2016. Eggs are mostly provided by Chief Joseph Hatchery with some local broodstock collection occurring in 2020.

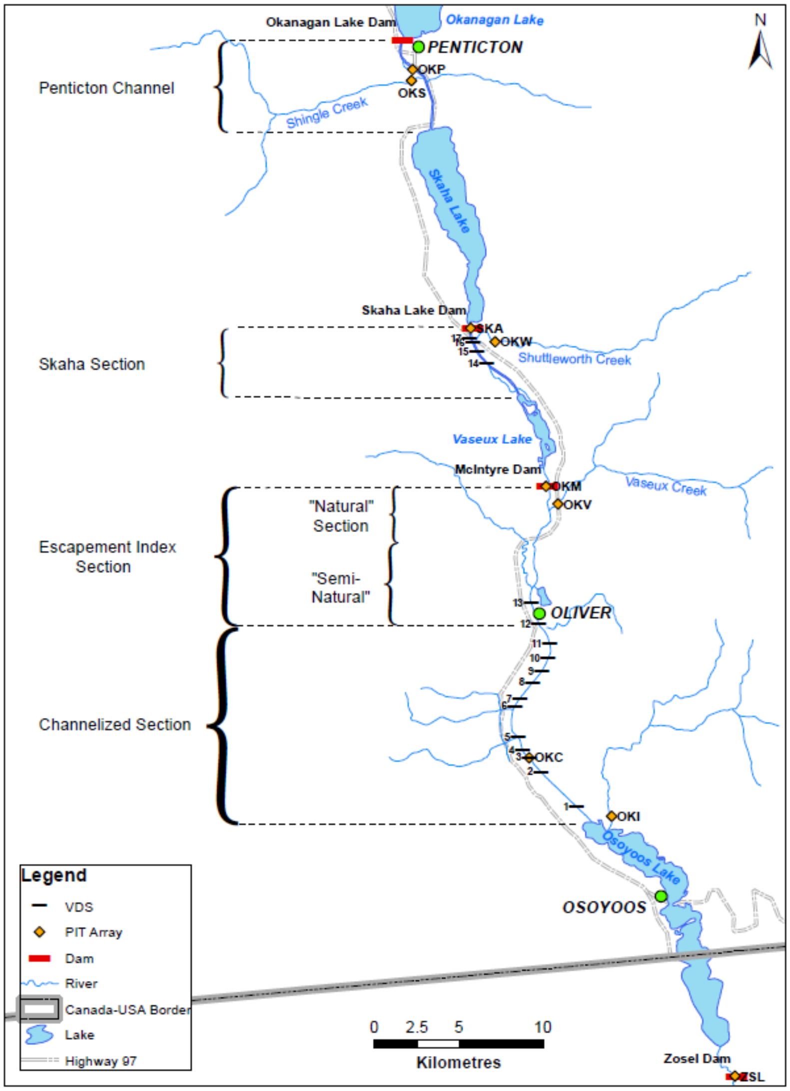

Figure 1. Map of PIT arrays in the Canadian Okanagan River basin and the furthest upstream array in the United States (source: Okanagan Nation Alliance Fisheries Department (2020) adapted from Fryer et al. 2020[1]).

[1] *Fryer, J., D. Kelsey, H. Wright, S. Folks, R. Bussanich, K. Hyatt, D. Selbie, and M. Stockwell. 2020. Studies into Factors Limiting the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2018. CRITFC technical Report 20-01. URL: https://www.critfc.org/wp-content/uploads/2020/04/20_01.pdf*

Egg to Fry Incubation
Water Management
The Okanagan Basin has a fish and water management tool (FWMT) which is used for promoting sockeye salmon production in Skaha and Osoyoos lakes, though other fish species are considered. The benefits of the FWMT likely extend to Chinook, as they spawn and rear in similar locations to sockeye. The FWMT is a coupled set of biophysical models of key relationships (climate, water, fish, and property) used to predict consequences of water management decisions for fish and other water uses. The FWMT improves sockeye fry production by reducing density independent losses due to variations in the amount and timing of controlled river discharge. The Okanagan Basin Agreement in 1982 outlined sockeye-friendly flows for the FWMT to assist in making water release decisions at the Okanagan Lake dam. Flood, scour, and desiccation events can be controlled with the FWMT. ONA has undertaken climate change flood assessments and work is ongoing to include climate change into the FWMT model.
Sedimentation
Studies on sockeye egg incubation indicate that the Okanagan River has high oxygenation (9-13 parts per million [ppm]). Development issues can happen at 6 ppm, and survival issues can happen at 4 ppm. In channelized sections of the river, where intragravel oxygen tests indicate lower oxygenation levels, egg survival is roughly 30-50%; whereas natural portions of the river have egg survival estimates of 60-70%. Channelized sections of the river have high abundances of macrophytes, and sockeye salmon egg have been found that have a black egg disease, which is potentially influenced by the effects of invasive Eurasian milfoil (*Myriophyllum spicatum*) and fine sediment trapping. The Okanagan River Restoration Initiative (ORRI) has restored some channelized portions of the river, increasing egg survival to 70-80% in those areas. Sedimentation in channelized portions is greater than 5%, in natural areas it is 2%, and in ORRI restored portions, sedimentation is less than 1%. Sedimentation tests have not been conducted in the U.S. portion of the river. The Okanagan basin is wide and has a low gradient with fertile soils. Much of the land is used for agriculture that and the riverbanks are protected through berms and dikes, which results in lack of activation of the flood plain, bank destabilization during high flows and reduced riparian zones. Climate change projections indicate higher fall and winter flows with rain as the dominant precipitation instead of snow, however, the channelized portion of the river cannot absorb higher flows and there are studies underway to estimate the absorption potential. Some of the restored sections of the river include *cross over* areas, where the old river crosses the channel. Fish have been spawning in the cross over areas, but fish have not been seen spawning in locations where spawning habitat has been restored. Restoration initiatives prioritize cross over areas and historic river channel reconnections for restoration, though opportunities are limited due to development.

Juvenile Rearing and Smolt Emigration
Survival, Travel Time, and Temperature
The relationship between smolt outmigration timing, survival and warming waters in the Okanagan is complex and not well understood, but it could be an important bottleneck for Chinook in the Canadian Okanagan. In the U.S., where natural production is relatively successful, natural-origin smolt outmigration occurs April through July before the water

temperature reaches 20°C. Natural-origin smolt survival from the mouth of the Okanagan River to McNary Dam averages only about 18%. Survival estimates from Omak Pond to McNary Dam are higher for hatchery subyearlings (~25%) and yearlings (~50%). Travel time from Omak pond to Bonneville Dam is similar for hatchery yearlings (33 days) and subyearlings (32 days) and slightly longer for natural-origin subyearlings (37 days) that are tagged and released later but further down the river. In the Canadian portion of the river, fry have been observed from April to late summer. Water temperature in the South basin of Osoyoos averages 22°C by July 2, so natural smolt outmigration may not be successful if they are delayed getting through the lakes. PIT tag detection efforts are currently underway for hatchery origin fish. While migration is still in progress for 2021 yearlings (brood year 2019), preliminary survival estimates from release to the OKC PIT detection array (Figure 1) are roughly 77%, from the OKC array to Zosel Dam survival estimates are roughly 31% with a travel time of 30 days, and from Zosel Dam to Rocky Reach Dam survival estimates are 63%. Estimated survival to Rocky Reach Dam from release is 15% in 2021. The majority of hatchery fish released in April 2021 emigrated through Zosel Dam by mid-June before river and lake temperatures were above 20°C. The development of a life cycle model may be useful to capture juvenile survival assumptions and model outcomes given known and presumed reach survivals and the potential benefits of management actions for generating more returning adults.
Habitat
ONA conducted off-channel rearing habitat surveys and found that the channelized sections of the river are not connected to off-channels. There are very few fully accessible off-channels accessed in the natural section and through one restored side channel. Many of the side channels are managed as part of the South Okanagan Wildlife Management Area and flow is controlled through sluice gates which are often plugged with debris. Salmon fry observed in the off-channels when sluice gates are plugged are unlikely to exit and contribute to adult Chinook production. More studies, including upcoming ONA PIT tagging and acoustic studies, could provide estimates of entrainment in the off-channels. The channelized portion of the river contains VDS where smolts can remain vulnerable to predation before and after the drop. Additionally, the VDS limit invertebrate production, reducing feeding opportunities for rearing fry. ONA has proposed replacing the VDS with riffles and spawning gravel to create more rearing and spawning habitat. Restoration efforts could also include reconnecting side-channels for additional rearing habitat and improving the sluice gates for fish passage.
Predation
Predation studies on Okanagan summer Chinook are currently lacking. Studies in the mainstem Columbia River on Upriver Bright fall Chinook from the Hanford Reach indicate high productivity, but low parr to smolt survival through the McNary Reservoir (~35% survival to McNary Dam). There are high consumption rates of juvenile *Oncorhynchus* spp. by non-native predators such as smallmouth bass (*Micropterus dolomieu*; 60% of diet) and walleye (*Sander vitreus*; 90% of diet); however, the abundance of non-native predators remains unknown. In the Canadian portion of the Okanagan River, smallmouth bass and yellow perch (*Perca flavescens*) have been found in Skaha, Vaseux, and Osoyoos Lakes. In some studies, smallmouth bass were found to have few samples with salmonids in stomachs and were not active in the littoral zone at

the time of the survey (April), whereas yellow perch were actively feeding on Kokanee fry (82% of stomach contents). The habitat found in the lakes and river is good for these non-native species, though walleye have not migrated since initial discovery during a study in the U.S. portion in the early 2000s. In Washington's angler-driven suppression programs, bag limits have been removed for walleye and smallmouth bass. Water management could be used to disrupt nesting behavior of smallmouth bass. A life cycle model and additional predation studies could provide information on estimates of predation and help prioritize restoration activities.

Adult Migration to Spawning Grounds
Temperature
At Wells Dam, median return timing for summer Chinook is July 24 (data years 2002–2020), coinciding with river temperatures at Malott reaching 22°C by July 19 and after Oroville reaches 22°C on July 2. The timing of fish returning to the Canadian portion of the Okanagan indicate that roughly 1-3% would arrive before the thermal barrier sets up, with 25-27% of the fish holding in the Similkameen River and roughly 70% holding in the Columbia until late August, delaying their migration further. Estimates of pre-spawn mortality from radio tagging studies and passage estimates compared with spawner counts appear to be low. Brief breaks in the thermal barrier (<22°C) in the U.S. portion of the Okanagan sometimes occur one or more times per summer; however, the water coming out of Lake Osoyoos rarely drops below 22°C during these events which would cause a higher proportion of Canadian fish to hold in the Similkameen or suffer a longer exposure to warm water temperatures. Osoyoos Lake undergoes a temperature-oxygen squeeze in nearly all years, reducing available lake habitat for migrating fish. Generally, the central and south basins of the lake become unusable. This is not an issue for Skaha and Okanagan lakes, and little is known about the situation with Vaseux Lake. From mid-July to the third week of August, temperatures in the Okanagan River at Oliver typically exceed 22°C. There are many small groundwater seeps, primarily in the natural section, but no cold, deep holding areas. ONA Elders have mentioned that putting the river back to a natural state will reconnect to thermal refuges. For Fraser River sockeye, two management tools incorporate environmental conditions such as temperature and discharge. Management adjustments are used by proactively adding fish to escapement targets by impacting total allowable catch limits and fishery openings to increase the likelihood of achieving escapement targets. Management adjustments are based on difference between abundance estimates on the spawning grounds and potential spawning escapement estimates, which can be based on models with environmental covariates. Difference between estimates (DBE) occur through en route mortality, estimation errors, and unaccounted for catch. The DBE is larger when temperature or discharge is high.
Migration Barriers
At Zosel Dam, PIT tags indicate that roughly 40% (2010-2021) of migrating adults made multiple attempts at passing the dam. However, there is some uncertainty if all Chinook are attempting to migrate upstream as spawning does occur in the gravel below the dam. Video counting of sockeye salmon at Zosel indicated no delay. Median passage timing of spring run Chinook at Zosel is July 20 and for summer-run Chinook is October 5. summer Chinook tend to migrate past Zosel Dam and the OKC arrays in larger numbers after water temperatures fall below 20°C. PIT detection efficiency at Zosel Dam is lower than at the OKC array (Figure 1)

especially during higher water flows earlier in the summer, when fish can pass through the open spill gates rather than migrating through the fish ladders where the PIT arrays are located. McIntyre Dam creates an additional migration delay, though monitoring data so far indicates that fish can pass overshot gates with little issue. At the VDS, jump success creates migration delays, but the cumulative effects of the 17 drop structures are unknown. The need for improvements to the fish ladder at Skaha Lake Dam was identified but remain to be implemented. The fishway at Okanagan Dam was activated for brief periods in the fall of 2019 and 2020, and despite trying to keep Chinook from passing, they were confirmed in Peachland (~40 km upstream) and in Kalamalka Lake (~100 km upstream). It is likely that they migrated through the open spill gates of the dam during high water.

Habitat Availability

The Okanagan River has undergone many changes over the last 100 years. There are currently only 3 km of natural and 2 km of semi-natural river sections with 30 km of channelized river. These changes have reduced river length by 50% and resulted in a 90% loss of riparian vegetation. Through ORRI, some sections of the river have been restored, but in some cases, fish are utilizing the old riverbed (cross over) instead of the restored sections. The ORRI program has worked to restore side channel connections and floodplains where possible. Restoring the river will help connect thermal refugia.

<u>Overview of the RAMs process:</u> The risk assessment methodology (RAMs) process conducted in November 2020 was aimed at assessing risk for Okanagan River Chinook (see attachment 7 for more information).

Risk = exposure * consequence.
Exposure = spatial extent * temporal frequency.
Consequence = change in returning adults.

<u>Overview of the OWG process:</u> The Okanagan Work Group reviewed qualitative factors that affect survival for different life stages. Geographic extent of factor was a cumulative value from negligible to extreme (1-50+ km of river). Persistence of factor was a value from one time per life stage to entire life stage. Severity of factor, or mortality, was a value from negligible or slight (<1 to 10%) to extreme (71-100%). Factors were weighted as important using the persistence and severity rankings (Table 1), and geographic extent was applied as a multiplicative to the weight.

Table 1. Weighting scheme to rank factors.

Persistence of Factor	Entire life stage	0	5	6	7	8	9
	10 times per life stage	0	4	5	6	7	8
	5 times per life stage	0	3	4	5	6	7
	one time per life stage	0	2	3	4	5	6
	negligible	0	1	2	3	4	5
	unknown	0	0	0	0	0	0
		unknown	negligible (<1%)	slight (1-10%)	moderate (11-30%)	serious (31-70%)	extreme (71-100%)
		Severity of Factor					

Ranking from Table 1 are multiplied by the geographic extent as identified in Table 2.

Table 2. Geographic extent multiplicative factor.

Cumulative Geographic Extent	Multiply outcome by:
negligible (<1 km of river)	2
small (1-5 km of river)	3
moderate (1-10 km of river)	4
large (1-20 km of river)	5
extreme (1-50+ km of river)	6
unknown	1

Weighting Exercise

Egg to Fry Survival

Results from RAMs process:

In general, egg incubation factors were low or very low risk, due to the use of the FWMT.

Recommendations: An assessment can be undertaken to incorporate Chinook for potential changes to the FWMT guidelines. A gap analysis is underway to incorporate climate projections into water planning. Restoration of streambeds should be designed around enhancing hyporheic flows.

Results of the OWG Workshop:

Egg incubation factors were generally rated low risk, with sedimentation and oxygenation rated moderate risk due to their persistence and severity. Predation was rated as a moderate impact on survival but had small geographic extent. The OWG noted that egg survival is slightly worse in channelized sections of the river.

Factor	Cumulative Geographic Extent of Factor	Persistence of Factor	Severity of Factor	*Importance on Survival*	*Extent of Importance*
Sedimentation	small (1-5 km of river)	Entire life stage	moderate (11-30%)	7	21
Oxygenation	small (1-5 km of river)	Entire life stage	moderate (11-30%)	7	21
Predation	unknown	Entire life stage	slight (1-10%)	6	6
Non-optimal water temperatures	unknown	10 times per life stage	slight (1-10%)	5	5
Poor water quality (aquatic pollution)	moderate (1-10 km of river)	5 times per life stage	negligible (<1%)	3	12
Low flows	small (1-5 km of river)	one time per life stage	negligible (<1%)	2	6
High flows	small (1-5 km of river)	one time per life stage	negligible (<1%)	2	6

Juvenile Rearing and Smolt Survival

Results from RAMs process:

During the RAMs process, seven factors were identified which were similar to the egg stage. The risks were determined to be higher for the rearing stage. Inadequate quality or quantity of rearing habitat and predation were noted to have a very high impact on survival. Risks were expected to increase in the future.

Recommendations: Create additional side channel habitat. Replace undershot gates with overshot gates at Zosel Dam. Perform predator abundance surveys and start targeted removal and suppression programs. Begin experimental removal of milfoil in Vaseux Lake.

Results of the OWG Workshop:

Predation, poor rearing habitat quality and complexity, off-channel entrainment, and high temperatures were ranked as high risk, both in terms of importance to survival and geographic extent.

Recommendations: Restoration efforts should prioritize reconnecting side channels and installing fish screens to reduce entrainment in off-channels.

Factor	Cumulative Geographic Extent of Factor	Persistence of Factor	Severity of Factor	*Importance on Survival*	*Extent of Importance*
Predation	extreme (1-50+ km of river)	Entire life stage	serious (31-70%)	8	48
Predation	extreme (1-50+ km of river)	Entire life stage	serious (31-70%)	8	48
Poor rearing habitat quality/complexity	moderate (1-10 km of river)	Entire life stage	serious (31-70%)	8	32
Off-channel entrainment	large (1-20 km of river)	Entire life stage	moderate (11-30%)	7	35
High water temperatures	extreme (1-50+ km of river)	5 times per life stage	moderate (11-30%)	5	30
Predation @ VDS/dams	large (1-20 km of river)	10 times per life stage	slight (1-10%)	5	25
Poor water quality	small (1-5 km of river)	5 times per life stage	slight (1-10%)	4	12
Water flows	small (1-5 km of river)	one time per life stage	slight (1-10%)	3	9

Adult Survival

Results from RAMs process:

Migration routes and barriers, loss of safe migration routes, and high temperatures were identified as very high risk. These will continue to be very high risk into the future.

Recommendations: Observe Chinook passage at dams and VDS. Create cool water refuges, potentially through a hypolimnetic siphon on Skaha dam to reduce outflow temperatures (though an old study indicated this could be costly, however new technologies are available as well as new funding sources to mitigate the effects of climate change). Where possible, remove VDS and plant riparian vegetation along the river.

Results of the OWG Workshop:

High water temperatures, migration impediments (e.g., VDS), and available spawning habitat were rated as moderate impacts on survival. Geographic extent increased the risk of migration impediments and high water temperatures to high. The OWG noted that limited spawning habitats is likely not an issue with the low population abundance, but may become an issue in the future if abundances increase.

Recommendations: Riparian restoration for river shading and the use of shade cloths. Restoration projects aimed at utilizing the old riverbed (cross over sections). Reduce migration delays, allowing migrating spawners to reach the next thermal refugia during short reprieves of high stream temperatures.

Factor	Cumulative Geographic Extent of Factor	Persistence of Factor	Severity of Factor	*Importance on Survival*	*Extent of Importance*
High water temperatures	extreme (1-50+ km of river)	Entire life stage	moderate (11-30%)	7	42
Migration impediments (VDS)	extreme (1-50+ km of river)	10 times per life stage	slight (1-10%)	5	30
Available spawning habitat	moderate (1-10 km of river)	Entire life stage	negligible (<1%)	5	20
Low flows	negligible (<1 km of river)	negligible	slight (1-10%)	2	4
Poor water quality (aquatic pollution)	moderate (1-10 km of river)	negligible	negligible (<1%)	1	4

Insights and Feedback
Main freshwater survival issues affecting Okanagan summer Chinook

○ Alterations of the Canadian section of the Okanagan River from the natural state to the man-made channelized segments with flow control structures have reduced habitat complexity and the processes that provide capacity to support Chinook salmon.
    ○ There is little riparian zone remaining, which leads to:
        ▪ Increased water temperatures due to lack of shade
        ▪ Reduced stream habitat complexity (e.g., woody debris is absent from the channel leading to less frequent pool-riffle habitats)
        ▪ Less riparian zone reduces habitat and food for insects and other salmonid prey
    ○ Channelization has:
        ▪ Reduced habitat complexity, such as the frequency of pools, riffles and deep water habitats for salmon
        ▪ Armoring of the channel banks increases stream temperatures, as rip rap conveys heat into the stream
        ▪ Reduced connections with the hyporheic zone
    ○ Flow control structures
        ▪ create constrictions and areas where piscivorous fishes and birds aggregate to eat juvenile salmon
        ▪ can delay upstream migrating salmon and increase exposure to high river temperatures
○ High water temperatures during adult migration (often) and juvenile outmigration (variable)
○ Potentially high predation mortality on juveniles in the Canadian Okanagan lakes, Lower Okanagan River (near Wells Pool) and Columbia mainstem

Differing abundance patterns
○ The serious impacts of channelization and flow control structures in the Canadian Okanagan have created unnatural habitats that are low quality for Chinook survival and production compared to other types of rivers where there are healthy Chinook stocks.
Potential mitigation options

○ Screening or improvements to off-channel habitats to prevent entrainment
○ Freshwater habitat restoration, including:
    ○ reconnecting the system with old river channels and flood plain
    ○ riparian restoration
    ○ spawning habitat restoration
○ Application of fishery management adjustments to buffer escapements when hot water occurs or is predicted to cause en route mortalities and losses
○ Identify cool water management opportunities (e.g., management in cold tributaries vs mainstem of the river)
○ Spawning habitat restoration in the channelized sections in Canada. The intent is to mitigate for the loss of spawning habitat that resulted from channel confinement, VDS gradient control structures, and elimination of the ecological process that recruit Large Woody Debris from the riparian zone and its interaction with the natural river channel to

create pools, riffles, and spawning habitat. o Habitat manipulations to reduce predation (e.g., milfoil control or non-native predator suppression) o Suppression, disruption of non-native predators through angling regulations and management actions such as netting or electrofishing. o Reduce migration delays at dams and VDS
Activities to increase knowledge of freshwater survival issues
o Studies on predation abundance and suppression or control efforts o Studies on migration delays at dams and VDS o Sedimentation studies and egg survival in U.S. section of the river o PIT and acoustic telemetry studies to identify temporal/spatial areas of mortality, critical habitats, and fish behavior o Continued PIT application to Chinook released in Canada to understand juvenile and adult migrations and survival relative to flow and temperature
"One action to help"

o Participants were asked "If they could only take ONE action, which would have the greatest benefit toward the objective of reestablishing/strengthen summer Chinook in the Canadian portion of the Okanagan River basin, what would it be? (Don't consider cost, feasibility, etc.)"
o Four workshop participants response were largely aimed at restoring the river to natural conditions.
    o "If there is only one action that we could take towards restoring Okanagan Chinook, it should be to dechannelize the river and restore the natural floodplain to the greatest extent possible."
    o "As my one and only action for the benefit of summer Chinook salmon to become established in the Okanagan River in BC, remove Zosel Dam."
    o "I agree that re-naturalization of the watercourses (removal of flow impoundment and control structures such as dikes, dams, vertical drop structures) would probably bring the greatest benefit."
    o "Cool the river!"

Workshop Materials	
Attachment Number	**Title**
1	Okanagan Chinook Survival Workshop Introduction.pptx
2	Okanagan Chinook Survival Background Document_June 17 2021.docx
3	Egg - Incubation Studies - K.Alex.pptx
4a	Smolt - US Migration - C.Baldwin.pptx
4b	Smolt - CAN Migration - E.McGrath.pptx
4c	Smolt - Additional Studies - E.McGrath.pptx
4d	Smolt - Col R Predation - G.McMichael.pptx
4e	Smolt - CAN Predation - E.McGrath.pptx

4f	Smolt - VDS Restoration - K.Alex.pptx
5a	Adult - US Migration - C.Baldwin.pptx
5b	Adult - CAN Temperature - E.McGrath.pptx
5c	Adult - CAN Migration - E.McGrath.pptx
5d	Adult - Migration Delays - K.Alex.pptx
5e	Adult - Habitat Availability - K.Alex.pptx
5f	Adult - Management Adjustments - M.Forrest.pptx
6	All Sessions - RAMs Risk and Mitigation - C.Lagasse.pptx
7	RAMs Summary Report
8	Weighting Exercise (workshop worksheet).xlsx

Attendees

Attendee	Country	Affiliation
Andrew Murdoch	U.S.	Washington Department of Fish and Wildlife
Athena Ogden*	Canada	Fisheries and Oceans Canada
Bill Templin	U.S.	Alaska Department of Fish and Game
Bill Tweit*	U.S.	Washington Department of Fish and Wildlife
Brian Riddell	Canada	PSC Commissioner
Casey Baldwin*	U.S.	Confederated Colville Tribes
Catherine Michielsens	PSC	Pacific Salmon Commission
Charles Barr	U.S.	Oregon Department of Fish and Wildlife
Chris Fisher	U.S.	Confederated Colville Tribes
Chris Kern	U.S.	Oregon Department of Fish and Wildlife
Christine Mallette	U.S.	Oregon Department of Fish and Wildlife
Chuck Parken*	Canada	Fisheries and Oceans Canada
Cory Lagasse*	Canada	Fisheries and Oceans Canada
Dani Evenson	U.S.	Alaska Department of Fish and Game
Elinor McGrath*	Canada	Okanagan Nation Alliance
Geoff McMichael*	U.S.	Mainstem Fish Research
Howie Wright	Canada	Okanagan Nation Alliance

Attendee	Country	Affiliation
Jeff Fryer	U.S.	Columbia River Intertribal Fish Commission
Jessica Gill	PSC	Pacific Salmon Commission
John Rohrback	U.S.	Confederated Colville Tribes
Kaitlyn Dionne	Canada	Fisheries and Oceans Canada
Kari Alex*	Canada	Okanagan Nation Alliance
Kory Ryde	Canada	Fisheries and Oceans Canada
Lauren Weir	Canada	Fisheries and Oceans Canada
Matt Laramie	U.S.	United States Geological Survey
Maxine Forrest*	PSC	Pacific Salmon Commission
Mike Matylewich	U.S.	Columbia River Intertribal Fish Commission
Rick Klumph	U.S.	Pacific Salmon Commission Commissioner
Ryan Benson	Canada	Okanagan Nation Alliance
Ryan Lothrop	U.S.	Washington Department of Fish and Wildlife
Skyeler Folks	Canada	Okanagan Nation Alliance
Tommy Garrison	U.S.	Columbia River Intertribal Fish Commission

* Denotes a presenter

OKANAGAN CHINOOK SURVIVAL WORKSHOP SUMMARY

July 14, 2021

1:00 pm – 5:30 pm PDT (Webinar)

The Okanagan Work Group (OWG) was established by the Pacific Salmon Commission (PSC) in 2019 and was charged to coordinate and monitor efforts by both countries to increase the return of Okanagan River summer Chinook (*Oncorhynchus tshawytscha*) to the Canadian portion of the watershed. This workshop was aimed at understanding supplementation programs at Chief Joseph Hatchery in Washington and the kł cp̓əlk̓ stim̓ Hatchery in British Columbia, goals for rebuilding the Chinook population in the Canadian portion of the river, and identify problems, issues, or potential solutions to the development of a bilateral supplementation program.

Key Findings and Recommendations
○ A carefully designed bilateral supplementation program would be of value in restoring Chinook populations in the Canadian portion of the Okanagan River and can be accomplished if resources to address impediments are made available.
○ A bilateral supplementation program design should be consistent with current Canadian and U.S. design and hatchery scientific principles. Consider alternative broodstock collection locations and building adult holding facilities.
○ Coordination between hatcheries and utilization of expertise on each side of the border will be key to a successful program. Consider integrating juvenile release strategies across the border.
○ Careful monitoring of harvest and developing harvest management plans is important to control interception of spawners destined for the Canadian portion of the river. It is especially critical to consider marking protocols for hatchery releases considering mark selective fisheries in the U.S. portion of the Okanagan.
○ Consider ecological interactions of hatchery releases, including predation bottlenecks and predator monitoring.
○ The workshop participants provided opinions on the impediments to a bilateral supplementation program. They identified the top four barriers as: (1) adult holding capacity in the U.S., (2) permitting, capture and transport of live adult fish from the U.S. to Canada (hatchery and river spawners), (3) natural-origin broodstock availability; and (4) logistical challenges (e.g., trucks, holding locations).

Background
Historically, First Nations heavily fished Chinook at Okanagan Falls, but since the 1900s, hydropower dams, gradient control structures, irrigation dams, and channelization have reduced available natural-state spawning and rearing habitat in the Canadian portion of the river by 84%. Okanagan River summer Chinook represent one biological population that spawns in both the U.S. and Canada. Abundance in the U.S. has increased considerably since the early 2000s but has remained low in Canada. The U.S. component of the population is roughly 100 times larger than the Canadian component (U.S.: 4,000-14,000 spawners, Canada: <80 spawners). The Canadian component is identified as endangered, whereas the U.S. component is healthy and often exceeds escapement objectives. Similar sized watersheds to the Canadian portion have an average carrying capacity of 9,800 adult Chinook (+/- CV of 14%). While passage has been restored at three of the irrigation dams allowing more access and the Okanagan River Restoration Initiative (ORRI) has reconnected side channels and restored spawning habitats in the last decade, the Canadian component escapement remains low. Habitat restoration projects are ongoing and planned for the future. The U.S. component of the population is approximately 30% hatchery origin fish from Chief Joseph Dam and the Canadian component is roughly 10% hatchery origin fish. Supplementation in Canada may help mitigate demographic issues with the low abundances seen, help recolonize newly accessible habitat, and could increase abundance more quickly than would happen naturally. Supplementation programs in the U.S. and Canada can be helpful during the period of habitat restoration.

Glossary

Common Terms

pHOS = proportion of Hatchery Origin Spawners
- HOR = Hatchery Origin Return
- HOS = Hatchery Origin Spawner

pNOB = proportion of Natural Origin Broodstock
- NOS = Natural Origin Spawner

PNI = proportionate natural influence (integrates hatchery and natural) metric to determine how much the hatchery population influences the population's adaptive status. It is calculated as:

$$PNI = \frac{pNOB}{pNOB + pHOS}$$

If PNI is 0.5, then both environments are having equal influence on adaptation. The Hatchery Scientific Review Group (HSRG) recommended a PNI of at least 0.67 so that the natural environment is dominating the influence on adaptation. Similarly, the Canadian Department of Fisheries and Oceans (DFO) Scientific Advisory Secretariat Review (DFO 2018; Attachment 6) recommended a PNI of at least 0.72 since more than 50% of the fish will be of natural-origin and close to three-quarters of the fish will be of natural origin, posing a lower risk to genetic diversity and natural adaptation.

Three main management measures influencing PNI:

1) Hatchery release numbers;
2) Proportion of hatchery fish visually marked for fisheries;

3) Proportion of marked fish selectively harvested (or removed at weirs and hatcheries); and 4) Proportion of natural origin fish in the broodstock.
Program Types
Segregated: Hatchery fish are kept separate from natural-origin fish; the hatchery population represents a distinct population that is reproductively isolated from naturally spawning populations. *Integrated:* One population, genetic mixing in the hatchery and on the spawning grounds; the natural environment drives the adaptation and fitness of a composite population of fish that spawns in both a hatchery and in the natural-origin.

Hatchery Program Principles
Hatchery Scientific Review Group (HSRG)
In 2000, the U.S. Congress established a hatchery reform project with a team of scientists to develop principles and recommendations to reform hatcheries in the Pacific Northwest. The HSRG developed three principles to reform hatcheries (HSRG 2009; Attachment 8). - Principle 1: develop clear, specific, quantifiable harvest and conservation goals. - Principle 2: design and operate hatchery programs in a scientifically defensible manner. - Principle 3: monitor, evaluate, and adaptively manage hatchery programs. The HSRG conclusions included: ▪ Manage hatchery broodstock to achieve either proper genetic integration with, or segregation from, natural populations; ▪ Promote local adaptation of natural and hatchery populations; ▪ Minimize adverse ecological interactions between hatchery- and natural-origin fish; ▪ Minimize effects of hatchery facilities on the ecosystem; and ▪ Maximize survival of hatchery fish.
Canadian Population Classification System
Hatchery production is a management tool for the conservation of small or endangered natural populations, fish production, stock assessment, and stewardship/education objectives. Hatchery-origin spawners (HOS) pose risks to fitness and genetic diversity of natural-origin fish; these risks can be mitigated some through proper design of the program. DFO enhancement programs have been developed as integrated populations, spawning in both hatchery and natural environments with gene flow between each component. PNI levels developed by the HSRG are utilized in DFO programs to evaluate, classify, and monitor levels of hatchery influence and genetic risk. The Wild Salmon Policy (WSP) informed a population classification system (DFO 2018; Attachment 6), which is reflective of the adaptive state of integrated hatchery populations based on the proportion of natural-origin spawners (NOSs) and HOSs. Increased genetic risk is associated with population designations that have increasing hatchery influence. Hatchery production should be undertaken as part of a broader recovery effort, designed in stages from high pHOS (designation E in table below) to low pHOS (designation A in table below). HOSs have a lower fitness than NOSs based on scientific studies, and the HOSs are discounted by an

assumed 80% ($pHOS_{eff}$ or relative reproductive success [RRS]).

Designation		$pHOS_{eff}$	pNOB	PNI	WSP	Comments
A	Wild	≤ 0.02	n/a	n/a[1]	NN ≥ 0.96 HN ≤ 0.04 HH ≤ 0.0004	Designated wild populations that do not have hatchery programs; strays from out-of-basin hatchery production are limited to <3% per year.
B	Wild-stray influenced	>0.03	n/a	n/a[1]	NN < 0.96 HN > 0.04 HH > 0.001	Population without hatchery program that receives strays from out-of-basin hatchery. A very large fraction of fish are wild but gene flow modelling suggests a long-term decline in *PNI*.
C	Integrated-wild	≤ 0.28	≥ 0.72	≥ 0.72	NN ≥ 0.52 HN ≤ 0.40 HH ≤ 0.08	Hatchery production is managed to keep WSP wild fish >50%.
D	Integrated-transition	≤ 0.5	≥ 0.5, <0.72	≥ 0.5 <0.72	NN ≥ 0.25 HN ≤ 0.50 HH ≤ 0.25	*PNI* > 0.5 ensures natural-origin influence predominate but wild fish are in the minority
E	Integrated-hatchery	> 0.5	< 0.5	< 0.5	NN ≤ 0.25 HN > 0.5 HH > 0.25	Net gene flow from hatchery environment and most fish are hatchery origin, < 25% of fish are wild.

Chief Joseph Hatchery

Under the principles of the HSRG, the Chief Joseph Hatchery's (CJH) primary objective is to meet obligations for ceremony and subsistence harvest of the Colville Confederated Tribes (CCT) and increase harvest opportunities for all anglers. Additionally, the CJH works with the mid-Columbia Public Utility Districts to meet hydro-system mitigation objectives. The CJH works to restore abundance, productivity, and temporal-spatial diversity of natural-spawning Chinook in the Okanagan Basin. Yearlings and subyearlings are released at CJH for the segregated program, and for the integrated program fish are released at Similkameen and Omak ponds. The Colville Tribes operates a rotary screw trap to estimate smolt abundance, but smolt outmigration is difficult to track due to the inability to operate the trap year-round.

Program size targets:

- Segregated program: up to 900,000 smolts; 520-540 hatchery origin brood
- Integrated program: up to 1,100,000 smolts; 640 natural-origin brood

Escapement objectives:

- 7,500 total spawners
- 5,250 natural origin spawners

The CJH utilizes preseason forecasts from the Technical Advisory Committee[4] and a life cycle model to manage returning populations, including reaching broodstock goals and assessing harvest plans. An in-season implementation tool is used to implement decision rules, to assess status and trends, and estimate in-season pHOS. Broodstock collection occurs at the mouth of the Okanagan River via purse seine. The eggs used in the integrated program have a high percentage (>60%) of natural-origin parents. The eggs for the segregated program come from first generation returns from the integrated program. A mark selective sport fishery (MSF) removes some of the excess hatchery fish which reduces the numbers of segregated program fish that spawn in the natural environment to minimize HOSs, though some straying happens (~5%).

[4] TAC is a committee of tribal, state and federal biologists established by the US v Oregon parties to provide technical advice. The Colville Tribes are not a member of TAC.

Segregated fish are adipose fin marked but only a portion have a CWT. The integrated program fish are adipose fin marked with CWT. Estimates of segregated and integrated program returns are assessed post-season in the CWT lab. Since 2010, the 10-year average of total escapement (7,299) has been slightly below the escapement objective (7,500); however, the average natural-origin (NOS) escapement (5,325) has exceeded the escapement target (5,250). The five-year running average of pHOS (24%) is below the long-term upper limit of 30%, primarily due to MSFs at the mouth of the Okanagan, which began in 2011. The five-year running average of PNI (0.80) exceeds the long-term objective of 0.67 or greater.
kł cp̓əlk̓ stim̓ Hatchery
The kł cp̓əlk̓ stim̓ Hatchery, run by Okanagan Nation Alliance (referred to as ONA Hatchery throughout this document) in Penticton began operations in 2014 focusing on sockeye salmon. The hatchery began releasing Chinook from BY2016 with a release group of just over 10,000 subyearling fry. Since the Chinook program's inception, an estimated 70,351 have been released. A portion of these fish have been released with adipose fin marks and PIT tags (33,599), and a smaller portion released with adipose fin marks and CWTs (3,383). The ONA Hatchery transports eyed eggs from CJH and when available, collects brood stock from the Canadian portion of the Okanagan River. No eggs were transported in brood year (BY) 2018, due to low abundance at the CJH. Broodstock collection from the Canadian section of the Okanagan River occurred in BY2017 and BY2020 at low levels (2-3 fish collected each year) and the hatchery has been cryopreserving Chinook milt since 2016. The ONA Hatchery released yearlings and subyearlings from BY2019, due to space limitations and competing priorities. In November 2020, 20,000 yearlings were released from BY2019 and the remaining BY2019 fish (roughly 20,000) were released in April 2021. Approximately 23,000 PIT tagged fish will be released from BY2020. Transporting eyed eggs from the U.S. to Canada requires permits with the Canadian Food Inspection Agency (CFIA) and Introductions and Transfers Committee (ITC). Female broodstock are tested in the U.S. for infectious hematopoietic necrosis (IHN) and viral hemorrhagic septicemia (VHS). When adult Chinook abundance allows, 15,000-50,000 eggs from CJH are set aside in a reduced temperature regime to manage size. The CJH broodstock is typically from 3-10 females. The objective for the Chinook Conservation Hatchery program is to increase abundance during these early years and have Chinook recolonize habitats that were previously inaccessible due to irrigation and flood control dams in Canada. Discussions about marking and tagging of the hatchery fish released in Canada need to occur for bilateral coordination. Currently, all the Okanagan summer Chinook hatchery fish in Canada and the U.S. are adipose fin marked. The external marking enables the hatchery programs to visually distinguish hatchery from natural origin fish for brood stock. It also enables mark selective fisheries to harvest these fish, which helps manage the PNI, but these fisheries reduce the survival and abundance of Conservation Hatchery fish that are homing to Canada. Thus, there are conflicting objectives with the PNI management and Conservation Hatchery programming. One option is to apply PIT or CWTs to 100% of the non-adipose fin marked Conservation Hatchery fish that are released in Canada to enable their identification during brood stock collection and spawning ground sampling. This option would increase the survival through the mark selective fisheries for the fish that are part of the Conservation Hatchery program. The spawning ground programs in Canada and the US currently sample fish for CWT and PIT tags and collect biological samples (e.g., age, sex, length, adipose fin presence, etc.), and the field procedures may need modification to sample tags from

non-adipose fin marked Chinook.

There is a need for more investigation about the relative survival of summer Chinook released in Canada among different release strategies (e.g., time of year and location) in order to optimize stock rebuilding and to consider any trade-offs with local adaptation objectives.

Hatchery Management Theory and Recovery in Practice

Hatchery and Genetic Management Plans (HGMP)

Historically, the Similkameen hatchery program started with BY1989 alongside the Wenatchee and Methow summer Chinook programs. Broodstock were collected from Wells Hatchery because at the time the Okanagan-bound and Methow-bound fish were not distinguishable, and fish were spawned as one large group, resulting in a homogenous population and genetic similarities.

Gene flow is expected between the U.S. and Canadian portion of the watershed. Comparisons between the Similkameen and Okanagan river Chinook indicated that there was low-to-absent genetic differentiation observed and high genetic diversity. Using microsatellite parentage-based tagging (PBT), which is based on single nucleotide polymorphisms (SNPs), natal fidelity to Canada was determined. Natal fidelity has been backed up with non-genetic observations of U.S. hatchery marked fish in Canadian portion, observation of lower proportion of adipose fin marked fish in Canada, the size and proximity of the U.S. population, and historic and recent enhancement activity.

The current coastwide Chinook SNP baseline consists of over 122,000 individuals, but more samples from the Okanagan and Similkameen would help to develop a more robust genome. Analyses suggest there are high genetic similarities among the Okanagan population and Wenatchee, Similkameen, and Hanford populations. There has been no significant change in genetic diversity of the Okanagan population since the 1990s, and no changes have been seen with neutral genetic diversity. Adaptive genes that control run timing, maturation rates, and thermal tolerance could be changing, but labs have not been monitoring these genes. Okanagan yearlings have an older maturation schedule than nearby Wells Hatchery, based on CTC analyses (CTC 2021; Attachment 13).

Future of Supplementation Programs

Canadian Targets

Objective	Description	Spawners	Citation
Conservation	Recovery Target	1,000 (4-year geometric mean) and positive trend for population growth	Mahoney et al. 2021 (Attachment 9); DFO 2019 (Attachment 7)
Sustainable Fisheries	Spawners producing Maximum Sustained Yield (S_{MSY})	3,400	Davis et al. 2007 (Attachment 5)

A population viability assessment model (Mahoney et al. 2021; Attachment 9) used PIT tag and

CWT survival estimates to age-2 for subyearlings and yearlings from Wells Dam (CTC 2021; Attachment 13) to represent juvenile survival. Results are summarized below that illustrate chances of attaining the Recovery Target and Population Trend objectives in the short and long term for different scenarios of reduced mortality rates and hatchery supplementation:

	Recovery Target [1]		Population Trend [2]	
Mitigation Scenario	**Short-term (12 yr)**	**Long-term (30 yr)**	**Short-term (12 yr)**	**Long-term (30 yr)**
Baseline Conditions	Very Unlikely	Very Unlikely	Negative	Negative
Postulated Habitat Improvements				
10% Mort Reduction	Very Unlikely	Very Unlikely	Negative	Negative
30% Mort Reduction	Very Unlikely	Very Unlikely	Positive	Positive
50% Mort Reduction	Very Unlikely	Very Unlikely	Positive	Positive
Hatchery Supplementation				
50,000 per year	Very Unlikely	Very Unlikely	Positive	Positive
100,000 per year	Very Unlikely	Very Unlikely	Positive	Positive
150,000 per year	Unlikely	Likely	Positive	Positive
250,000 per year	Very Likely	Very Likely	Positive	Positive
500,000 per year	Very Likely	Very Likely	Positive	Positive

A conservation hatchery program should be designed as a staged approach to achieve PNI and proportion of hatchery-origin spawners effective ($pHOS_{eff}$) based on the Canadian Science Advisory Secretariat process and research document (DFO 2018 [Attachment 6]; Withler et al. 2018 [Attachment 12]). Three phases of the conservation hatchery program were identified based on the spawner abundance relative to the Recovery Target and the Spawner abundance that would produce the Maximum Sustain Yield (S_{MSY}), which is the average habitat capacity for this size of watershed. The three phases align with the science advice from DFO (2018; Attachment 6) and Withler et al. (2018; Attachment 12) for proportions of hatchery origin spawners and PNI. The conservation hatchery supplementation levels from the population viability analysis (PVA) were aligned with the three phases, however these supplementation levels can be refined in the future as more survival data are collected and the PVA model is improved to represent fish origin, PNI and pHOS.

Phase	Spawner Abundance	Primary Objective	Comments
Conservation (Recolonization)	<1,000	Increase abundance	• Reconnect and restore habitats, • Increase juvenile and adult survival • Higher hatchery production while addressing factors leading to low abundance
Integrated-transition	1,000 – 3,399	Increase fitness and local adaptation	• Improve river system to self-support Chinook • Transition hatchery program to have higher proportions of natural origin salmon
Integrated-wild	>3,400	Viable population that supports fisheries	• Hatchery production is managed to keep Wild Salmon Policy wild fish >50%

Phase	$pHOS_{eff}$	PNI	Comments
Conservation (Recolonization)	≥ 0.5	none	• Population imperiled by low abundance and threats to productivity • Higher hatchery production while addressing factors leading to low abundance
Integrated-transition	≤ 0.5	0.5 – 0.72	• Transition hatchery program to have higher proportions of natural origin salmon • Increase local adaption
Integrated-wild	≤ 0.28	≥ 0.72	• Hatchery production is managed to keep Wild Salmon Policy wild fish >50%

Phase	Hatchery Supplementation (estimates)	Comments
Conservation (Recolonization)	>250,000 (>65 pairs)	• Supplementation anticipated to **progressively increase** as abundance increases • Release strategy & **supplementation level refined** as new survival data collected (**PVA revisited & modified for PNI)** • Release strategy targeted that has **highest survival, but** multiple strategies used • Egg source anticipated to be **largely from US source**, with locally adapted brood stock used when practical
Integrated-transition	150,000-250,000 (40-65 pairs)	• **Supplementation level refined** to meet **genetically-based targets** for enhanced contributions • Release strategy **transitions to mimic natural life history** • Egg source from **locally adapted brood stock**
Integrated-wild	<150,000 (<40 pairs)	• **Supplementation level refined** to meet **genetically-based targets** for enhanced contributions • Release strategy **mimics natural life history** • Egg source from **locally adapted brood stock**

Challenges at kł cp̓əlk̓ stim̓ Hatchery

Current ONA kł cp̓əlk̓ stim̓ Hatchery capacity for subyearling and yearling smolts depends on sockeye production, but more capacity may come on line in the future.

Life Stage	Current Capacity
Eggs	100,000–500,000
Fry	100,000–500,000
Subyearling Smolts	100,000–500,000
Yearling Smolts	50,000–250,000

Brood Collection:

The majority of Chinook spawn in the natural area north of Oliver, BC, which presents logistical and accessibility issues. Broodstock collection occurs opportunistically alongside sockeye brood collection with a beach seine. Attempts to float the natural sections of the river have occurred, but they have proven difficult. Alternative strategies could be implemented such as stationary tangle nets or overnight sets, weir, and exploring alternative sites for collection.

Transfers:

Transporting adult Chinook from CJH to ONA kł cp̓əlk̓ stim̓ Hatchery requires CFIA and ITC permits and testing for disease. The distance between the locations will result in a long travel time that may require water changes if high mortality occurs. Chinook holding capacity is reduced when there are large sockeye run sizes. Translocating adults from CJH to the spawning grounds could help with the capacity issues at ONA kł cp̓əlk̓ stim̓ Hatchery. Transporting eggs requires similar permits and testing, but there are fewer logistical challenges. Streamside egg takes could be possible. Water conservation during the off-season to help with aquifer replacement could impose some challenges. If ONA Hatchery is relying on eggs from CJH, adding an additional 60 pairs will be difficult as CJH is maxed out for adult holding. One suggestion was to examine the feasibility of creating adult holding capacity at the WDFW Similkameen Pond site, which is near the border.

Rearing Strategies:

The ONA kł cp̓əlk̓ stim̓ Hatchery has limited space for rearing yearlings or subyearling smolts. Over-winter rearing requires use of chiller to keep fish sizes down to avoid precocity. There is more capacity when rearing smaller fry or subyearlings and less time in the hatchery will limit hatchery selection effects on the population. However, most U.S. summer Chinook programs release yearlings based on studies showing better adult returns from yearling releases. There is potential to utilize Skaha and Osoyoos lakes as nursing habitat, with a release of fry in the fall. However, a smaller yearling program might be more efficient in terms of getting fish to come back to the spawning grounds despite space issues. Testing rearing release groups using PIT tags could identify the most effective release strategy. There are cost considerations and biological effectiveness with each strategy. Evidence from Vancouver Island and Fraser River (Quesnel) hatcheries indicate releasing subyearlings into a local lake can be successful, though competition and predation from invasive fish might play a role in successfully utilizing nursing habitat in the Okanagan.

Future Chinook Facility:

The ONA is in the process of securing funding for a Chinook-specific hatchery in Oliver on Osoyoos Indian Band land, which could solve some of the capacity issues at the Penticton Hatchery. The hatchery would have more room for adult holding and would reduce travel time from CJH. The hatchery could have volitional releases directly into the river (e.g. similar to the Similkameen and Omak pond programs). This location is at the primary Chinook spawning grounds (natural stream channel). The Penticton hatchery is located at the northern end of the spawning range, which is useful for sequential imprinting.

Challenges at Chief Joseph Hatchery

Smolt Releases:

CJH generally does not meet its overall smolt release target, and in 2020, it only made 50% of the target, and in 2021 it reached 77% of the target release numbers. Primary factors for not meeting release goals have been identified as lower than expected fecundity and low pre-spawn survival. If the hatchery is low on females, CJH can switch from subyearling to yearling production. Additional factors contributing to low smolt releases have been chiller failure, green-to-eyed egg survival, egg-to-fry survival, and egg-to-smolt survival. Additional broodstock gathered to address these concerns cannot be held at CJH. If abundance is low, preservation of natural-origin fish takes priority, and support for the Canadian Conservation Hatchery program could be difficult during low abundance years.

Brood Collection:

CJH objective is to collect broodstock locally to conform to HSRG principles. Brood collection via purse seine is effective, but during cool, high-flow years effectiveness is hampered. The collection works best when a thermal barrier prevents fish from moving up into the Similkameen River. These fish would be good for the Canadian program, but they cannot be held at CJH. Consideration of additional options, such as incubation trailers or an adult holding facility near Similkameen River, could alleviate the adult fish holding issues on the U.S. side. The lower Okanagan weir cannot be installed until flows are low, which is late in the migration and not efficient for brood stock collection. Since late arriving fish spawn lower in the Okanagan, fish collected at the weir are not a good source for Canadian brood stock, as they may be adapted to different habitat conditions. A good brood collection site in the lower Similkameen (Kline site) was washed out during the 2018 floods and is no longer viable. Additional site options have not been identified since the Kline site was discontinued. Collection at Osoyoos Lake (Zosel) Dam could be utilized with minor modifications to sockeye collection sites at fish ladders or modifications to the spill basins of Zosel Dam. Collection efficiency at Zosel Dam would depend on water levels.

Juvenile Life History Strategies:

Subyearlings have a lower return rate than yearlings and when shortages occur, CJH reduces the subyearling program in favor of yearlings. More subyearlings can be raised per adult, but more yearlings return per adult. Precocity is not generally an issue but can be if growth rate and feed content are not managed appropriately. There has been a higher than desired return rate to CJH for fish acclimated in the Okanagan, but this should not be an issue if ONA Hatchery can take broodstock or eggs.

Fish and Egg Transfers:

Transfers of eggs and adults fall under state, federal, tribal, and provincial processes and permits. The process for transferring eggs has been worked out since ONA Hatchery came on line and more consideration would be needed to transfer adult fish. An HGMP is provided to NOAA regarding impacts to Endangered Species Act (ESA) listed fish with details about where and how fish were collected, raised, and released. It is unclear if a transboundary supplementation program would require a new HGMP or an addendum. CCT Business Council would need to approve of an updated permit.

Transboundary supplementation:

Initially, a transboundary plan might be a sink for U.S. Natural Origin Rivers (NORs) due to broodstock extraction, and another concern is Canadian HORs and NORs straying to the Similkameen at a high rate due to the thermal refuge. This could be an important research objective to help with the design of the Conservation Hatchery Program. In the integrated program, the objective is to maintain high escapement to the spawning grounds, but to stay within pHOS goals. The management objective in the segregated program is to support fisheries and remove HORs, which may undermine Canadian escapement objectives if the integrated Canadian hatchery production is adipose fin marked. Getting NORs on to the spawning grounds in the U.S. and removing HORs for harvest could be a problem if the Conservation Hatchery program is in phase 1 of recovery. If Canadian fish move upstream into the Similkameen, CJH objectives may not be met, and the pHOS could be too high in the Similkameen to achieve the PNI objective. If the spawner monitoring detects issues with hatchery fish straying from Canada to the

US Okanagan/Similkameen, then imprinting studies may be needed to reduce straying. Imprinting and straying are important considerations for planning the Conservation Hatchery Program strategies and supporting any local adaptations that may be valuable for fish returning to Canada (e.g., migration timing that is prior to the thermal migration barrier).
Monitoring and Evaluation
The genetics labs at DFO, Washington Department of Fish and Wildlife, and Abernathy Fish Technology Center (U.S. Fish and Wildlife Service) can share data, analyze whole genomes, and review historical samples, if desired. Increasing the sample genome through sample collection, ensuring phenotypes and length and weight estimates are included in samples will increase robustness. Sampling generally costs about $20 per PBT genotyping. Increasing the sample genome will allow researchers to track adaptive gene flow, pHOS, and PNI. It is possible, when capacity is limited, to have more families with fewer eggs to have more unrelated fish returning to spawn, though at CJH that is difficult. From a genetics standpoint, if low numbers of families are used continuously, that can have big swings in diversity. Monitoring of Osoyoos and Skaha lakes for predation by non-native species will help determine feasibility of using as nursery lakes when capacity at the hatchery is limited.

Insights and Feedback
Survey
The workshop leaders asked participants to reply to a survey to gauge opinions on the bilateral supplementation plan. Survey questions can be found in the Appendix. There was one question to gauge opinions regarding the impediments to developing a bilateral supplementation plan. Participants were asked to rank 18 challenges along the following scale: Unknown; Not Applicable; Not an Impediment; Somewhat of an Impediment; Moderate Impediment; and Extreme Impediment. There were three open-ended questions asking for additional information on barriers and potential solutions. Fifteen participants responded to the survey. Two participants responded prior to an adjustment of the survey wording. Each opinion question response was categorized on the following scale: 0 = Unknown; Not Applicable; 1 = Not an Impediment; 2 = Somewhat of an Impediment; 3 = Moderate Impediment; and 4 = Extreme Impediment. This facilitated averaging and ranking across the question responses. Responses for each question were averaged, then the average scores were ranked among all questions. Count of each response by question was also reviewed. Responses to the four open-ended questions were reviewed to identify themes. When a response included multiple themes, it was broken up by theme.
Results
Every participant noted that developing a bilateral supplementation plan for Okanagan Chinook was appropriate. Six participants noted caveats in developing a plan, listed below. Responses to the open-ended questions integrated many facets of fisheries management, including harvest management, environmental concerns, and collaboration across agencies. Themes on

coordination and collaboration were mentioned 20 times in the open-ended responses and themes regarding environmental concerns (e.g., predation, broodstock availability) were mentioned 5 times. Funding and harvest themes were mentioned in the open-ended responses three times and once, respectively.

The following nine challenges were ranked by at least one participant as an extreme impediment to implementing a bilateral supplementation plan (Figure): permitting for egg transfers (1), permitting, capture, and transport of live adult fish (3), U.S. funding (1), logistical barriers (2), knowledge of relative survival of different rearing strategies (1), juvenile capacity limits in the U.S. (2), brood capture techniques (1), adult holding capacity in the U.S. (5), and adult holding capacity in Canada (1).

Three challenges, with an average score greater than 2.5, were identified (Figure 2). The highest scoring impediment to implementing a bilateral supplementation plan was adult holding in the U.S. with an average rank of 3.15 (n = 13, sd = 0.80). Permitting, capture, and transport of live adult fish from the U.S. to Canada (hatchery and river spawners) was ranked as the second largest impediment with an average rank of 2.93 (n = 15, sd = 0.70). Natural-origin brood stock availability was ranked third with an average rank of 2.54 (n = 13, sd = 0.66).

Eleven challenges were ranked as medium impediments, with an average score between 1.50 and 2.50 (Figure 2). These challenges included funding in both the U.S. and Canadian programs, permitting for egg transfers, rearing strategies, location and capture techniques of broodstock collection, adult holding capacity in Canada, and juvenile capacity limits at both facilities.

Four challenges, with an average score less than 1.5, were ranked as lowest impediments (Figure 2). These challenges include collaborative assessments, release locations, and homing to release sites. The lowest ranked impediment was bilateral data sharing, with a rank of 1.07 (n = 15, sd = 0.26), indicating current data sharing between the U.S. and Canada is good.

Caveats to developing a bilateral supplementation plan

- Transboundary permits, disease control, warm river conditions during adult migration.
- The Okanagan Chinook problems are more complex than they are for Okanagan Sockeye. Accordingly, a Pacific Salmon Commission bilateral program would benefit from the expertise in both countries, which would provide a higher chance of success compared to a program developed outside of the PSC process.
- Recognize autonomy of each country's efforts and programs.
- It should be closely coordinated with the CJH program in the U.S.
- Design of the program must be consistent with the standards for supplementation programs that both nations have adopted. A long-term source of funding should be identified in each nation that includes monitoring and evaluation costs as well as direct supplementation program.
- In so far as possible this should remain an effort among a smaller local group of people and governments. Expanding the scope will also expand the potential difficulties.

Below are responses to the open-ended questions

Are there additional barriers that were not identified during the workshop?
In your opinion, to what extent does the barrier impede a bilateral supplementation plan?

- It seems like the border is a barrier. I feel like we should be looking at this from the eyes of First Nation Peoples of the Okanagan. It seems like a political barrier.

- Harvest management strategies. Once implementation begins is there how will you monitor potential harvest of adult returns?
- A coordinated, bilateral supplementation plan that has been designed to achieve multiple objectives for the management entities
- Collection of broodstock (also harvest) in the U.S. may intercept spawners destined for Canada. This may affect Canadian spawning abundance, efforts for development of locally adapted broodstock, and meeting broodstock goals in Canada. This barrier does not impede a bilateral supplementation plan.
- Climate change. Chinook in the U.S. have to work around a thermal barrier in the lower Okanagan and holding temps in the Similkameen that are barely suitable. The temperature barrier in Lake Osoyoos is more extreme than the temps in the U.S. Okanagan. If climate change warms the river earlier and later then summer Chinook might not be a viable long term option for Chinook in Canada.
- I believe not enough discussion was given to marking protocols for potential hatchery releases. These fish need to be easily distinguished Canadian and US origin, especially if Canadian releases end up straying into spawning tributaries. 2.) Coordination with US hatchery committees that oversee the US mitigation programs both in terms of the hatchery and natural environments. Especially if requests from Canada for brood or surplus eggs to part of the overall supplementation plan. 3.) Worried about impact of a Chinook program being housed out of the sockeye hatchery which is funded with US mitigation dollars.
- Supplementation must avoid creating or increasing "predator pits"; implementing predator management programs may need to be an element in program design.
- I'm sure that there are additional but unknown barriers that will come forward if a plan actually begins to be implemented. For instance, what actions should be taken when a certain resource (broodstock, water temperature, etc.) becomes limited.

Are there potential solutions that could be successful in mitigating or removing the barriers identified to implementing a bilateral supplementation plan?
- Continued working collaboratively. - Collaboration with U.S. Chinook harvest monitoring programs - Is an adult holding facility feasible at the WDFW Similkameen pond site, and what would be the costs for construction and annual operation? This may present an opportunity to collect fish from the Similkameen River or from Zosel Dam (prior to the spawning season), and then hold them for fish health testing to then either transport fertilized eggs or live fish to Canada. - Planning - Making sure current programs aren't affected - Explore feasibility of collecting broodstock or fish for trap and transport at Zosel Dam fishway - Funding always helps. If hatchery fish end up being the solution, raising yearlings somewhere else than the sockeye hatchery would help. Give greater consideration to translocation of [natural origin] NO adults for supplementation. Perhaps a longer or slower timeline for supplementation. - Jointly developed Juvenile program with agreed to release strategies. - A poet once said "Good fences make good neighbors." Taking time to define the priorities, boundaries and responsibilities of each party involved will go a long way to resolve barriers.
Do you have additional information to share with the Okanagan Work Group on Bilateral Supplementation Programs?
- A long-term bilateral supplementation and monitoring plan that involves annual reporting, performance assessment against objectives, and then refinement/adjustment of the plan will help build the abundance of the Okanagan Chinook population on both sides of the border. The Pacific Salmon Commission's support for and development of a bilateral supplementation program could be a fine example of cross-border cooperation and collaboration to address some of the complex problems facing salmon and to successfully restore stocks and benefit fisheries in both countries.

Opinions

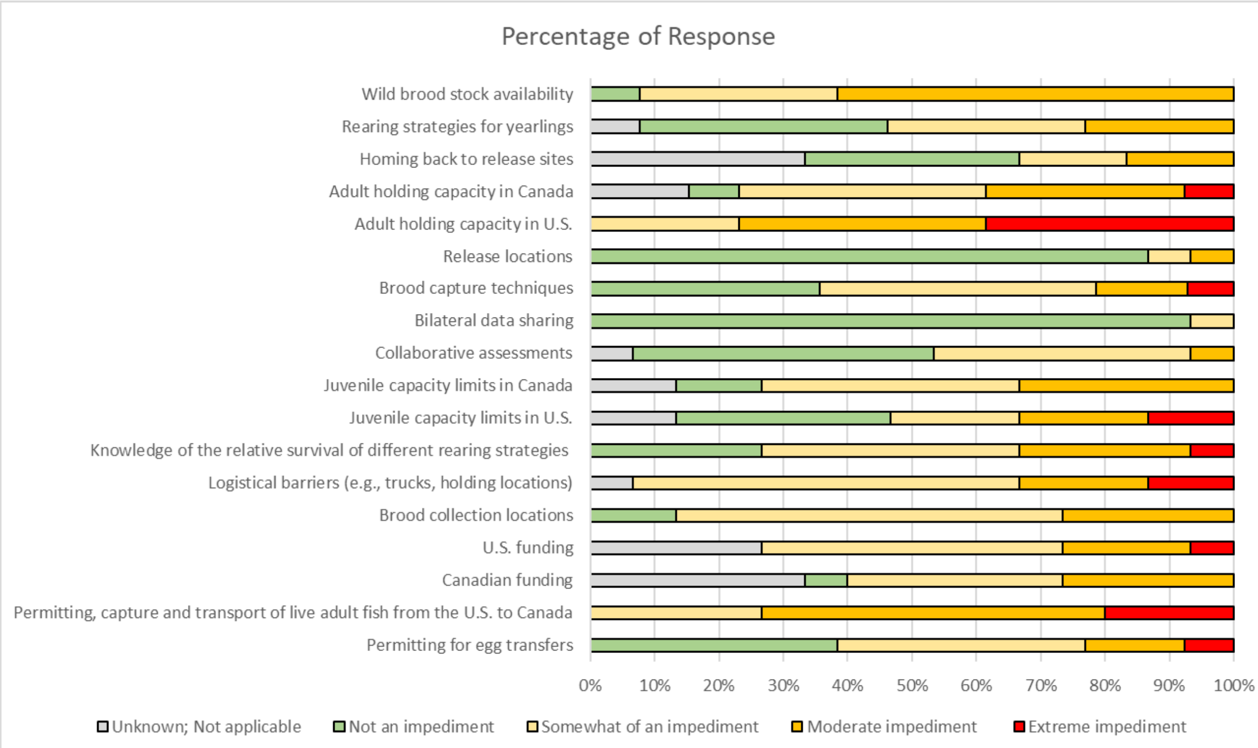

Figure 1. Percentage of responses each category of ranking for each barrier to developing a bilateral supplementation plan.

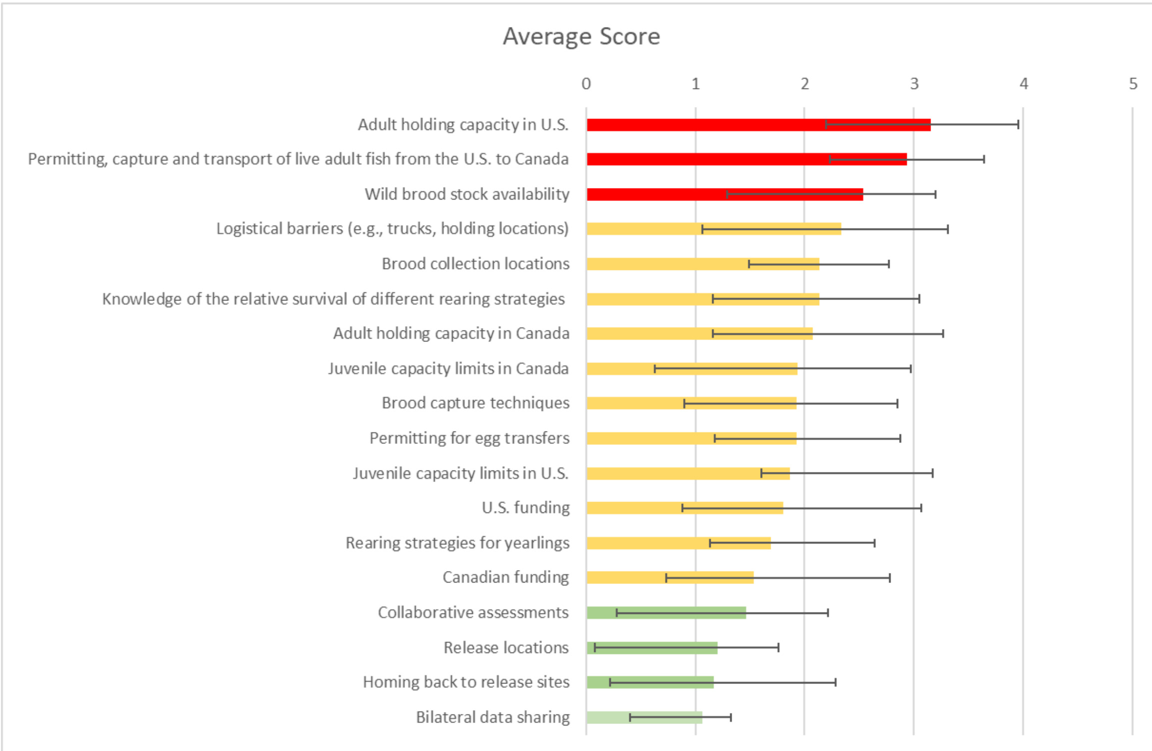

Figure 2. Average score of barriers to developing a bilateral supplementation plan ranked by participants.

Workshop Materials	
Attachment Number	**Title**
1	Bilateral Supplementation Workshop Introduction (Sep 7 2021).pdf
2a	CJH presentation_CaseyB_PSTOWG_090921_part2.pdf
2b	Genetically-based targets for Enhanced Chinook contributions in Canada (Sep 7).pdf
2c	OWG_BilateralChinookWorkshop_HatcheryProgram_DanS.pdf
3a	Okanagan Chinook Canadian target program size (Sep 7 2021).pdf
3b	OWG_BilateralWorkshop_Part2_DanStefanovic.pdf
3c	CJH presentation_CaseyB_PSTOWG_090921_part3.ppt
4	cn_okanagan_genetics_MGL_sutherland_2021-09-07.pptx
5	Davis et al. 2007.pdf
6	DFO 2018.pdf
7	DFO 2019.pdf
8	HSRG 2009.pdf
9	Mahoney et al. 2021.pdf

10	McKinney et al. 2020 A mobile sex determining region.pdf
11	McKinney et al. 2020 Y-chromosome haplotypes.pdf
12	Withler et al. 2018.pdf
13	CTC 2021.pdf

Attendees

Attendee	Country	Affiliation
Andrea Pearl*	U.S.	Confederated Colville Tribes
Ben Sutherland*	Canada	Fisheries and Oceans Canada
Bill Templin	U.S.	Alaska Department of Fish and Game
Bill Tweit*	U.S.	Washington Department of Fish and Wildlife
Casey Baldwin*	U.S.	Confederated Colville Tribes
Chad Jackson	U.S.	Washington Department of Fish and Wildlife
Christine Mallette	U.S.	Oregon Department of Fish and Wildlife
Chuck Parken*	Canada	Fisheries and Oceans Canada
Colin McGregor	Canada	Fisheries and Oceans Canada
Cory Lagasse	Canada	Fisheries and Oceans Canada
Dan Stefanovic*	Canada	Okanagan Nation Alliance
Dean Allan	Canada	Fisheries and Oceans Canada
Doug Lofthouse	Canada	Fisheries and Oceans Canada
Elinor McGrath	Canada	Okanagan Nation Alliance
Flip Pryor	U.S.	Alaska Department of Fish and Game
Garrett McKinney	U.S.	Washington Department of Fish and Wildlife
Howie Wright	Canada	Okanagan Nation Alliance
Jessica Gill	PSC	Pacific Salmon Commission
Joel Harding	Canada	Fisheries and Oceans Canada
Kaitlyn Dionne	Canada	Fisheries and Oceans Canada
Kirk Truscott	U.S.	Confederated Colville Tribes
Kory Ryde	Canada	Fisheries and Oceans Canada
McCoy Oatman	U.S.	PSC Commissioner
Melissa Hack	Canada	Fisheries and Oceans Canada
Michael Tonseth	U.S.	Washington Department of Fish and Wildlife
Mike Matylewich	U.S.	Columbia River Intertribal Fish Commission
Norm Johnson	Canada	Okanagan Nation Alliance
Rick Klumph	U.S.	Pacific Salmon Commission Commissioner
Ryan Lothrop	U.S.	Washington Department of Fish and Wildlife
Shawn Narum	U.S.	Columbia River Intertribal Fish Commission
Tommy Garrison	U.S.	Columbia River Intertribal Fish Commission
William Gale	U.S.	U.S. Fish and Wildlife Service

* Denotes a presenter

Appendix

Survey given to participants

1. In your opinion, is developing a bilateral supplementation plan appropriate for Okanagan Chinook?
    a. If no or maybe, explain why.
    b. If yes, are there any caveats you would add about developing a bilateral supplementation program?

2. In your opinion, to what extent does each of the following barriers present an impediment to implementing a bilateral supplementation program.
    a. Permitting for egg transfers
    b. Permitting, capture and transport of live adult fish from the U.S. to Canada (hatchery and river spawners)
    c. Canadian funding
    d. U.S. funding
    e. Brood collection locations
    f. Logistical barriers (e.g., trucks, holding locations)
    g. Knowledge of the relative survival of different rearing strategies
    h. Juvenile capacity limits in U.S.
    i. Juvenile capacity limits in Canada
    j. Collaborative assessments
    k. Bilateral data sharing
    l. Brood capture techniques
    m. Release locations
    n. Adult holding capacity in U.S.
    o. Adult holding capacity in Canada
    p. Homing back to release sites
    q. Rearing strategies for yearlings
    r. Wild broodstock availability

3. Are there additional barriers that were not identified during the workshop? In your opinion, to what extent does the barrier impede a bilateral supplementation plan?

4. Are there potential solutions that could be successful in mitigating or removing the barriers identified to implementing a bilateral supplementation plan?

5. Do you have additional information to share with the Okanagan Work Group on Bilateral Supplementation Programs?

OKANAGAN CHINOOK BASELINE ASSESSMENT WORKSHOP SUMMARY

April 21, 2022

1:00 pm – 5:00 pm PDT (Webinar)

The Okanagan Chinook Work Group (OWG) was established by the Pacific Salmon Commission (PSC) in 2019 and was charged to coordinate and monitor efforts by both countries to increase the return of Okanagan River summer Chinook (*Oncorhynchus tshawytscha*) to the Canadian portion of the watershed. This workshop was aimed at understanding productivity and capacity of the Okanagan River.

Key Findings and Recommendations
○ Control for or robust enough monitoring for cross-border movement of adults (i.e., spawned in one place recovered in another); otolith microchemistry/stable isotope analysis natal areas and incubation areas differentiation.
○ Continued cross border collaboration is important. (Okanagan Basin Monitoring and Evaluation Program doesn't have capacity at this time)
○ Verify/review habitat assumptions for estimating carrying capacity, including incorporating climate change scenarios.
○ Life history model development for entire Okanagan summer Chinook population with best available data to inform where resources should go to maximize the effectiveness of recovery/enhancement efforts.
○ Improve understanding of climate change as it pertains to flow and water temperature as thermal barriers already exist today so as to inform decision makers of future actions.
○ Continue to expand tools and monitoring for expansion of northern pike into anadromous waters. eDNA is a cost-effective tool that should include additional monitoring and communications.
○ Explore the benefits that removing Enloe Dam has for water temperature, fish passage, etc.

Background
Workshop goal – Improve understanding of monitoring/assessment of productivity throughout the Columbia River basin, where/how to improve monitoring/assessment, and support collaboration.
Terminology

Productivity – typically measured in recruits per spawners, with density-dependent and density-independent components distinguished. Varies in relation to the factors that influence survival.

Production – the abundance of a cohort of Chinook at a life stage.

Capacity – the maximum abundance that can be supported by the environment.

Current Available Information
United States
Okanagan summer Chinook productivity is measured in adult to adult recruits per spawner. Productivity is estimated through two models – an empirical model and a habitat model. The empirical model is fit to observational data based on redd surveys, expanded to total spawners and natural-origin recruits with reconstruction of adult recruitment by age using Coded Wire Tag (CWT) data, but the new Similkameen-Omak (SMK) CWT data series has not been used yet. The habitat model is based on an Ecosystem Diagnosis and Treatment (EDT) model. The empirical model is a good fit for the observational data (1998–2016) and productivity is estimated at 4.5 with a capacity of 17,951. The EDT model productivity is estimated at 5.8 with a capacity of 16,296. Brood year (BY) 2014 and 2015 exhibited a strong density-dependence spawner-recruit relationship but could be confounded by extremely poor ocean survival. Average adult recruit per spawner is 2.3 and has been consistently over 2.0 for the last 10 years. The relationship between productivity and environmental indicators (as seen in the NWFSC Stoplight Chart) produced a negative slope with an R^2 of 0.34 under an offset of 1 year. A bad ocean year was tied to low productivity. The relationship is decent but noisy. There is good concurrence between the empirical and the habitat models. There has been good productivity over the last 20 years, and ocean conditions appear to have a strong influence. Density dependent effects in the habitat are unclear, hampered by lack of juvenile production and survival data and confounded by poor ocean conditions that have followed high spawner abundance.
Canada
The Canadian portion of the Okanagan River is highly channelized, and flows are highly controlled using 17 gradient control structures. The natural sections and Penticton Channel are surveyed annually by boat float and river walks for Chinook escapement and carcass surveys. An area-under-the-curve (AUC) method has been used since 2006 to provide an abundance index. Mark-recapture using PIT-tagged adults has been ongoing since 2020 and returning adults have been low. A larger return of PIT-tagged adults is expected in 2023 to provide mark-recapture estimates. There is not a regular juvenile monitoring program; however, juveniles were released from the hatchery with PIT tags in 2022 to track movement and survival to Zosel dam. It was suggested to review tag shedding and retention probability through carcass surveys.

Monitoring Responses
Smolt Monitoring

In the U.S. portion of the river, rotary screw traps are used to monitor and generate juvenile abundance estimates, run timing, juvenile size, and survival. Tagging natural-origin juveniles is an additional objective of the trap project. There are two traps, a 5-foot trap and an 8-foot trap, which operate April–June 24 hours per day, 5 days per week, pending debris and water flows. The rotary screw trap did not operate in 2020 due to COVID protocols. An additional beach seine and tagging project aims to tag up to 25,000 outmigrating smolts (fork length > 50 mm) just downstream of the mouth of the Okanagan. Smolts are collected from side channels and smolt collection from side channels has recently increased. Studies on otolith microchemistry indicate there is limited spawning of mainstem fish in the Okanagan, but if natural-origin mainstem spawners return to the Okanagan at a meaningful rate, managers can consider incorporating some of them into supplementation planning.

Okanagan Basin Monitoring and Evaluation Program (OBMEP)

The Okanagan Basin Monitoring and Evaluation Program (OBMEP) began in 2005 in response to a lack of data that existed throughout the Okanagan subbasin. OBMEP was designed to provide information on the transboundary status and trends of summer steelhead and their habitat. A subset of the habitat data are used for summer/fall Chinook. Data are evaluated through the EDT model. The spatial design of OBMEP is focused on collecting detailed data representative of a series of reaches as short as 1–4km in length. Habitat data at this scale are collected every four years. EDT is used as a data analysis tool for linking habitat attributes to survival factors for summer steelhead and summer/fall Chinook. The EDT model converts habitat data into a survival mosaic of habitat conditions across both time and space. Results of the model are presented in report cards for easy dissemination. Adult habitat capacity in the U.S. ranges from 8,242–16,575 and in Canada from 91–477, both for natural-origin recruits only. Juvenile habitat capacity ranges from 14,034–60,876. Assumptions in OBMEP limit capacity and abundance estimates. OBMEP modeling occurs every four years, with the next run in 2023. There are some uncertainties in ocean-type Chinook usage of habitat above large lakes, but other barriers could be influencing populations upstream of Osoyoos Lake. The OWG could tap into Traditional Ecological Knowledge to inform additional work.

In Canada, a similar program exists to the OBMEP habitat collection, but in less detail. Habitat monitoring includes observing riparian conditions, large woody debris, substrate, temperature logging, and collecting hydrometric data. Additional resources could be allocated for verifying/changing OBMEP assumptions, including updating the Fish Water Management Tool (FWMT), adding additional reaches, and incorporating climate change monitoring.

Habitat Monitoring

The OBMEP uses habitat data and informed fisheries opinions and applies them using the EDT model to produce inferences of habitat capacity for Chinook salmon. The estimates from this approach are corroborated by the empirical capacity estimates derived from Okanagan summer Chinook population dynamics in the U.S. sections. The approach has been applied to the Canadian River sections downstream of Skaha Lake dam, but not the accessible habitat that lies upstream of the dam. The approach has identified limited spawning habitat downstream of Skaha Lake dam and that the channel straightening and dyking has reduced both the quality and quantity (by 45%) of Chinook salmon habitat in this area. The EDT approach estimates the current summer Chinook habitat capacity is 477 spawners for the Canadian areas downstream of Skaha Lake dam, and that the capacity has increased from 119, estimated in 2009, presumably due to habitat restorations and improvements to water management. This modelling approach

can be helpful for guiding carrying capacity information, better understanding life history patterns for upstream/downstream of Lake Osoyoos, and connectivity to the U.S. population.
Tagging Efforts
Upper Columbia River tributaries are largely monitored using various (rotary screw and barge) smolt traps, however, it is challenging given spring run-off flows and timing for summer Chinook. Smolt trapping is expensive but is valuable in collecting survival estimates and changes of abundance through space and time. Peak flow occurs near the end of migration timing for summer Chinook. For example, Wenatchee River trap captures summer Chinook that are too small for PIT tags. The alternative approach is to mark fish otoliths but there is insufficient funding. Wenatchee system can have density-dependent issues during higher abundance years. Similkameen River might be a possible option given out-migrating summer Chinook smolts should be larger fish that can be PIT tagged. There is a possibility to use a hatchery PIT tag barge to estimate survival downstream of tributary smolt traps upstream or downstream of Lake Osoyoos, however, smaller tributaries are problematic. Colville Tribe operated a rotary screw trap downstream of Zosel Dam focused on sockeye in the mid-1990s but did encounter Chinook, with fish possibly rearing in Lake Osoyoos in May and June. There is documented movement upstream of juvenile fish from the U.S. side into Canada, which may be leading to small sample sizes downstream. Flows are likely sufficient for smolt traps near Zosel Dam and Lake Osoyoos, but there might be a need to consider use of a barge above Zosel Dam. Water temperatures in Lake Osoyoos outlet are above 20°C by mid/late May so monitoring in June is not warranted.
Other Systems
In the Wenatchee River, a population model was developed for spring Chinook to investigate the roles of management actions on the population's trajectories into the future (e.g., to 2070). The models were informed by tagging and mark-recapture data for the population collected at multiple life stages—from the subyearling emigrant life stage, to smolt emigration through the Columbia River, fisheries, and adult migration through the Columbia River and back to the Wenatchee River spawning grounds. The modelling approach was helpful to evaluate the potential relative benefits of various management actions and to inform discussions about management approaches in the near future.

Changes in the System
Water Temperature
Climate change is affecting the water temperature in the Okanagan River, with increases in the June–August water temperatures both at Mallot and Oroville. Temperatures during the peak migration period, from July–August, are expected to rise at least 2–3°C from the baseline levels of 18–21°C and reach levels of 22–24°C or even 25–26°C by the end of the century, depending on the climate change scenario. With the increase in river water temperatures, the number of hot water days per year will increase, along with an increase in the duration of hot water days. Changes to the thermal regimes during the adult migration, juvenile smolt rearing and emigration and egg incubation life stages will likely create selective pressures for Okanagan Chinook salmon. It will be valuable to monitor Okanagan Chinook productivity and responses to other

biological characteristics, such as spawn timing, fry emergence, adult and smolt migrations, to adaptively manage water resources in order to develop and implement mitigation options for the changing water temperature conditions. Okanagan Chinook exist in a watershed where the effects of climate change may have a more direct effect on their productivity.
Invasive Species
Monitoring of invasive fish species in the upper Columbia is focused on northern pike, as concerns about if/when they will reach anadromous waters increase. Primary detections below Grand Coulee Dam are noted using eDNA monitoring. eDNA is an affordable method to monitor and utilizing this method over a larger area with increased frequency should be considered. Suppression efforts are focused above Grand Coulee (i.e., Kettle Falls) within both U.S. and Canada waters of the Columbia River. Electrofishing has also been used to detect presence/abundance of northern pike. A feasibility study could be considered on the use/effectiveness of fences/barriers to limit spread. There are currently 13 species of invasive species within the Okanagan River basin.
Water Flow/Volume Changes
Fish Water Management Tool (FWMT) is a decision-support tool for both fishery and water managers to make informed decisions with regards to basin water volume, flow, and temperature. For example, 2022 has above normal snowpacks resulting in flooding that is expected to impact sockeye and kokanee; additionally, the increased and earlier outflow timing could impact Chinook fry emergence.
Dam Removal
Currently Enloe Dam is a barrier that prevents spring and summer Chinook salmon from using more than 150 km of river habitat in Washington and British Columbia. Recently, activities have been assessing the feasibility of removing Enloe Dam, however, information about the potential productive capacity of upstream habitats to produce spring and summer Chinook salmon have not been conducted. There is the potential to substantially increase the quantity of Chinook salmon habitat by removing the dam, since there are just over 200 km of river habitat available to the U.S. component of Okanagan summer Chinook currently. Due to the potential to remove this dam, it may be helpful to monitor any changes in the productivity and productive capacity that may occur if the dam is removed in the future and Chinook salmon are able to access the spawning and rearing habitats that are upstream of the dam site. Monitoring the biological response of spring and summer Chinook populations to dam removal could provide useful information to help with making decisions about removing dam barriers elsewhere in the U.S. and Canada.

Workshop Materials	
Attachment Number	**Title**
1.a	OWG Baseline Assessment Workshop Agenda 04.2022
1.b	Okanagan Chinook Productivity Baseline Assessment Workshop Introduction
2.	PSCOWG productivity workshop_CCT 042122
3.	OK Chinook Current Monitoring Apr20_2022 EM
4.	PSC summer Chinook Capacity - final

5.	FINAL_ObmepSlide4CH
6.	PSC Osoyoos_Limno_Pham_2022.04.19
7.	Murdoch presentation
8.	Sorel OWG workshop 4_2022
9.	SC4-21-22a
10.	Climate Change in the Okanagan 22.04.21
11.	Chinook baseline workshop Apr 2022
12.	Hyatt et al. 2020
13.	Northern Pike eDNA Monitoring Update
14.	D.Machin_Chinook baseline workshop Apr 2022 FWMT

Attendees

Attendee	Country	Affiliation
Andrea Pearl*	U.S.	Confederated Colville Tribes
Andrew Murdoch*	U.S.	Washington Department of Fish and Wildlife
Bill Tweit*	U.S.	Washington Department of Fish and Wildlife
Casey Baldwin*	U.S.	Confederated Colville Tribes
Chris Fisher*	U.S.	Confederated Colville Tribes
Christine Mallette	U.S.	Oregon Department of Fish and Wildlife
Chuck Parken*	Canada	Fisheries and Oceans Canada
Dani Evenson	U.S.	Alaska Department of Fish and Game
Dawn Machin*	Canada	Okanagan Nation Alliance
Elinor McGrath*	Canada	Okanagan Nation Alliance
Evan Smith*	Canada	Okanagan Nation Alliance
Howard Stiff*	Canada	Fisheries and Oceans Canada
Howie Wright	Canada	Okanagan Nation Alliance
Jessica Gill	PSC	Pacific Salmon Commission
John Artebaum*	U.S.	Confederated Colville Tribes
Kaitlyn Dionne	Canada	Fisheries and Oceans Canada
Keeley Murdoch*	U.S.	Yakima Nation
Kory Ryde	Canada	Fisheries and Oceans Canada
Mark Sorel*	U.S.	University of Washington
McCoy Oatman	U.S.	PSC Commissioner
Mike Matylewich	U.S.	Columbia River Intertribal Fish Commission
Rick Klumph	U.S.	Pacific Salmon Commission
Ryan Lothrop	U.S.	Washington Department of Fish and Wildlife
Sam Pham*	Canada	Okanagan Nation Alliance

Attendee	Country	Affiliation
Tommy Garrison	U.S.	Columbia River Intertribal Fish Commission

* Denotes a presenter

APPENDIX D: ANNUAL WORK PLANS

PACIFIC SALMON COMMISSION WORK PLAN
[2019-2020]
February 20, 2020

Panel / Committee: *The Okanagan Work Group (OWG) reports to the Pacific Salmon Commission.*

Date: *PSC Post Season Meeting, January 13-17, 2020.*

Update on Bi-lateral Tasks Assigned Under Current PSC Agreement:

The Pacific Salmon Commission assigned 9 tasks to the OWG on February 14, 2019:

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.

The OWG provided a report to the Commission on all 9 of these tasks at the 2019 Fall Meeting. A final report was delivered to the Pacific Salmon Commission office on December 16, 2019 it has been published in the PSC Technical Report series (Technical Report #42).

Obstacles to Completing above Bi-lateral Tasks:

None identified.

Outline of Other Panel / Committee Tasks or Emerging Issues:

At the 2019 Fall Meeting, the Commission identified that it will maintain the ad hoc Bilateral Okanagan Chinook Work Group, which will a) not be constituted under Article II of the Treaty; but will nonetheless b) provide an annual work plan for the Commission (initially in January 2020, and ongoing at the October Fall Meeting).

The OWG work plan tasks for this year are to:

1. Report historical and recent escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through 2019.
    a. This task will add another year of data collected by the management entities to the current analysis by the OWG and it would be included with the description of the escapement programs described in #7 below.
2. Conduct an exploitation rate analysis for Okanagan summer Chinook with CWT recovery data through 2018 and report the CWT statistics (e.g., mortality distribution tables, survival rates, maturation rates).
    a. This task will add another year of data to the current analysis by the OWG.
3. The Parties recognize the value of creating a baseline assessment of the current productivity and capacity of Okanagan River summer Chinook against which to measure the benefits of future habitat restoration and enhancement actions. The workgroup will coordinate a management entity exploration of alternative approaches to create such a baseline assessment. Alternatives may include a monitoring program for juvenile production, an analysis of spawner and recruit data, the use of habitat-based production models, or other approaches as appropriate.
4. Organize a workshop with the management entities that could be involved in a bilateral supplementation program for Okanagan summer Chinook. Identify U.S. and Canadian supplementation objectives. Review the current supplementation circumstances relative to the objectives. Identify any issues and options to address the issues. Summarize the findings and any recommendations for the Commission.
5. Have a session at the workshop (#5) with the management entities and others about the potential survival issues for juvenile and adult summer Chinook in the U.S. and Canadian sections of the Okanagan River. Examine the current survival monitoring projects relative to these issues and identify any gaps or modifications to existing study designs to learn about locations where the Okanagan summer Chinook may be experiencing poor survival. Summarize findings and recommendations for the Commission.
6. Have a session at the workshop to review the current escapement monitoring programs that the management entities use for summer Chinook in the U.S. and Canadian sections of the Okanagan River. Review the current escapement estimates relative to the CTC bilateral data standards for Chinook escapement indicator stocks. Develop the study design recommendations that could help the management entities achieve these CTC data standards and summarize them for the Commission.
7. At the workshop, have a session about the potential invasion of northern pike into the Okanagan River. Review the monitoring and control programs currently happening in the Columbia River upstream of Grand Coulee Dam. Seek advice from the management

entities and other experts about the steps and methods to prevent the spread of northern pike into the Okanagan River. Summarize the findings and recommendations for the Commission.

Potential Issues for Commissioners, including enhancement activities reported under Article V:

Development and implementation of a bilateral supplementation program involves multiple entities.

Planning for the bilateral supplementation program and the prevention of the northern pike spread into the Okanagan could begin during this cycle, and it could involve a workshop(s) among technical experts from both countries. The focus of northern pike discussions would be to develop an understanding of the gaps in current control efforts, and what assistance the Commission might usefully provide.

Resources for the workshop could become an issue that comes to the Commission. The OWG requests that funding be provided by the national sections for travel and per diem costs. If the Commission could sponsor this then it would indicate good support to initiate these efforts. A work group meeting can be tacked on to the workshop to facilitate other work tasks (e.g., escapement review, biologically-based management objectives, etc.).

Potential Issues for Committee on Scientific Cooperation

None identified.

Proposed Meeting Dates and Draft Agendas:

Meeting	Dates	Location	Meeting Objectives
OWG-Task List Planning	Feb 10-14	Conference Call & email	Outline more detailed plans to complete prioritized task(s) from Commission
PSC 35th Annual (& OWG)	Feb 20-21	Vancouver	1-2 day meeting to work on tasks
OWG-workshop planning	Mar/Apr	Conference Call & email	Check in on work tasks, planning for supplementation workshop
Supplementation workshop	Jun 15-19 (TBD)	Wenatchee	Support the development of a bilateral supplementation plan with options (~15-20 people)
OWG Workshop Summary	Jun 22-26	Conference Call & email	OWG to summarize main workshop findings, next steps and prepare report for Commission
OWG-task work	Sep	Conference Call & email	Check in on OWG work task analysis and report preparation for

Meeting	Dates	Location	Meeting Objectives
			Commission
PSC Fall Session	Oct (TBD)	(TBD)	OWG co-chairs attend and present supplementation plan and options to Commission, results from tasks

Status of Technical or Annual Reports:

The OWG provided a report to the Commission on all 9 of these tasks at the 2019 Fall Meeting. A final report was delivered to the Pacific Salmon Commission office on December 16, 2019 for and published in the PSC Technical Report series.

Comments:

None.

PACIFIC SALMON COMMISSION WORK PLAN
[2020-2021]
October 1, 2020

Panel / Committee:
The Okanagan Work Group (OWG) reports to the Pacific Salmon Commission.

Date: *PSC Fall Meeting, October 19-23, 2020.*

Update on Bi-lateral Tasks Assigned Under Current PSC Agreement:
The Pacific Salmon Commission approved the following work plan tasks to the OWG in February 2020:

1) Report historical and recent escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through 2019.
    a. Escapement has been reported for 2019, but further analysis is needed to generate estimates for hatchery- and natural-origin spawners.
2) Conduct an exploitation rate analysis for Okanagan summer Chinook with CWT recovery data through 2018 and report the CWT statistics (e.g., mortality distribution tables, survival rates, maturation rates).
    a. The exploitation rate analysis was completed through 2018.
3) The Parties recognize the value of creating a baseline assessment of the current productivity and capacity of Okanagan River summer Chinook against which to measure the benefits of future habitat restoration and enhancement actions. The workgroup will coordinate a management entity exploration of alternative approaches to create such a baseline assessment. Alternatives may include a monitoring program for juvenile production, an analysis of spawner and recruit data, the use of habitat-based production models, or other approaches as appropriate.
    a. Our plan was to engage the expertise at the Workshop (#4), however the workshop has not yet occurred due to COVID19, and this item has been carried forward to the 2020/1 work plan.
4) Organize a workshop with the management entities that could be involved in a bilateral supplementation program for Okanagan summer Chinook. Identify U.S. and Canadian supplementation objectives. Review the current supplementation circumstances relative to the objectives. Identify any issues and options to address the issues. Summarize the findings and any recommendations for the Commission.
    a. Our plan was for the Workshop (#4) was affected by COVID19, and this item has been carried forward to the 2020/1 work plan via remote teleconferencing approaches.
5) Have a session at the workshop (#5) with the management entities and others about the potential survival issues for juvenile and adult summer Chinook in the U.S. and Canadian sections of the Okanagan River. Examine the current survival monitoring projects relative to these issues and identify any gaps or modifications to existing study designs to learn about locations where the Okanagan summer Chinook may be experiencing poor survival. Summarize findings and recommendations for the Commission.

    a. This item was affected by COVID19, and it has been carried forward to the 2020/1 work plan via remote teleconferencing approaches.
6) Have a session at the workshop to review the current escapement monitoring programs that the management entities use for summer Chinook in the U.S. and Canadian sections of the Okanagan River. Review the current escapement estimates relative to the CTC bilateral data standards for Chinook escapement indicator stocks. Develop the study design recommendations that could help the management entities achieve these CTC data standards and summarize them for the Commission.
    a. This item was affected by COVID19, and it has been carried forward to the 2020/1 work plan via remote teleconferencing approaches.
7) At the workshop, have a session about the potential invasion of northern pike into the Okanagan River. Review the monitoring and control programs currently happening in the Columbia River upstream of Grand Coulee Dam. Seek advice from the management entities and other experts about the steps and methods to prevent the spread of northern pike into the Okanagan River. Summarize the findings and recommendations for the Commission.
    a. This item was affected by COVID19, and it has been carried forward to the 2020/1 work plan via remote teleconferencing approaches.

Obstacles to Completing above Bi-lateral Tasks:
The extent and duration of the circumstances associated with COVID19 was not anticipated, however for the next year the OWG will use remote teleconferencing approach to complete the tasks as best as can be done.

Outline of Other Panel / Committee Tasks or Emerging Issues:
At the 2019 Fall Meeting, the Commission identified that it will maintain the ad hoc Bilateral Okanagan Chinook Work Group, which will a) not be constituted under Article II of the Treaty; but will nonetheless b) provide an annual work plan for the Commission (initially in January 2020, and ongoing at the October Fall Meeting).

The OWG work plan tasks for this year are to:

1. Report historical and recent escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through 2020.
    a. This task will add another year of data collected by the management entities to the current analysis by the OWG and it would be included with the description of the escapement programs described in #7 below.
2. Conduct an exploitation rate analysis for Okanagan summer Chinook with CWT recovery data through 2019 and report the CWT statistics (e.g. mortality distribution tables, survival rates, maturation rates).
    a. This task will add another year of data to the current analysis by the OWG.
3. The Parties recognize the value of creating a baseline assessment of the current productivity and capacity of Okanagan River summer Chinook against which to measure the benefits of future habitat restoration and enhancement actions. The workgroup will coordinate a management entity exploration of alternative approaches to create such a

baseline assessment. Alternatives may include a monitoring program for juvenile production, an analysis of spawner and recruit data, the use of habitat-based production models, or other approaches as appropriate.

    a. A teleconference will be used identify and coordinate approaches.

4. Organize several virtual workshops with the management entities that could be involved in a bilateral supplementation program for Okanagan summer Chinook. Identify U.S. and Canadian supplementation objectives. Review the current supplementation circumstances relative to the objectives. Identify any issues and options to address the issues. Summarize the findings and any recommendations for the Commission.
    a. If the circumstances with COVID19 change by the summer of 2021, an in-person workshop maybe planned for July to achieve work plan items #4-7.
5. A teleconference with the management entities and others will focus on the potential survival issues for juvenile and adult summer Chinook in the U.S. and Canadian sections of the Okanagan River. The current survival monitoring projects relative to these issues will be reviewed and examined to identify any gaps or modifications to existing study designs to learn about locations where the Okanagan summer Chinook may be experiencing poor survival. Findings and recommendations will be summarized for the Commission.
6. A teleconference with the management entities and others will review the current escapement monitoring programs that the management entities use for summer Chinook in the U.S. and Canadian sections of the Okanagan River. The current escapement estimates will be reviewed relative to the CTC bilateral data standards for Chinook escapement indicator stocks. Any new escapement methodologies will be communicated to the OWG and other for review and feedback on study design recommendations that could help the management entities achieve these CTC data standards and summarize them for the Commission.
7. A teleconference with the management entities and others will focus on the potential invasion of northern pike into the Okanagan River. The monitoring and control programs currently happening in the Columbia River upstream of Grand Coulee Dam will be reviewed, and advice will be sought from the management entities and other experts about the steps and methods to prevent the spread of northern pike into the Okanagan River. The findings and recommendations will be summarized for the Commission.

Potential Issues for Commissioners, including enhancement activities reported under Article V:

Development and implementation of a bilateral supplementation program involves multiple entities.

Several short virtual teleconferences will be used instead of in-person meetings, depending on the COVID19 situation. If the COVID19 changes by the summer 2021, an in person workshop approach may be planned. Resources for the workshop could become an issue and the OWG requests that funding be provided by the national sections for travel and per diem costs. If the Commission could sponsor this then it would indicate good support to initiate these efforts. A work group meeting can be tacked on to the workshop to facilitate other work tasks (e.g. escapement review, biologically-based management objectives, etc.).

Potential Issues for Committee on Scientific Cooperation
None identified.

PACIFIC SALMON COMMISSION WORK PLAN
[2021-2022]
October 4, 2021

Panel / Committee:

The Okanagan Work Group (OWG) reports to the Pacific Salmon Commission.

Date: PSC Fall Meeting, October 18-22, 2021

Update on Bi-lateral Tasks Assigned Under Current PSC Agreement:

The Pacific Salmon Commission approved the following work plan tasks to the OWG in February 2021:

1. *Report historical and recent escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through 2020.*
    - ✓ Data through run year 2020 have been provided but not published in an OWG report.
2. *Conduct an exploitation rate analysis for Okanagan summer Chinook with CWT recovery data through 2019 and report the CWT statistics (e.g., mortality distribution tables, survival rates, maturation rates).*
    - ✓ Mortality distribution tables and CWT statistics have been updated through run year 2019, but not published in an OWG report.
3. *The Parties recognize the value of creating a baseline assessment of the current productivity and capacity of Okanagan River summer Chinook against which to measure the benefits of future habitat restoration and enhancement actions. The workgroup will coordinate a management entity exploration of alternative approaches to create such a baseline assessment. Alternatives may include a monitoring program for juvenile production, an analysis of spawner and recruit data, the use of habitat-based production models, or other approaches as appropriate.*
    - No work was conducted on this task due to competing priorities. The work group expects the results of the workshops conducted over the last year to inform a virtual workshop about a productivity baseline proposed for April 2022.
4. *Organize a workshop with the management entities that could be involved in a bilateral supplementation program for Okanagan summer Chinook. Identify U.S. and Canadian supplementation objectives. Review the current supplementation circumstances relative to the objectives. Identify any issues and options to address the issues. Summarize the findings and any recommendations for the Commission*.
    - ✓ A virtual workshop was held on September 9, 2021. There were 32 participants from 8 management entities, with 8 presentations. The workshop identified U.S. and Canadian supplementation objectives, reviewed the current supplementation circumstances relative to the objectives, and identified any issues and options to address the issues. A summary of the

workshop should be available in early October for workshop participants. A presentation is planned for the CIG as part of the new Work Plan Task 5.

5. *A teleconference with the management entities and others will focus on the potential survival issues for juvenile and adult summer Chinook in the U.S. and Canadian sections of the Okanagan River. The current survival monitoring projects relative to these issues will be reviewed and examined to identify any gaps or modifications to existing study designs to learn about locations where the Okanagan summer Chinook may be experiencing poor survival. Findings and recommendations will be summarized for the Commission.*
    - ✓ A virtual workshop was held on July 14, 2021. The workshop had 32 participants from 10 management entities, with 14 presentations. The current survival monitoring projects relative to these issues were reviewed and examined to identify gaps or modifications to existing study designs to learn about locations where the Okanagan summer Chinook may be experiencing poor survival. A presentation is planned for the CIG as part of the new Work Plan Task 5. A brief summary is in the Work Plan Comments section.
6. *A teleconference with the management entities and others will review the current escapement monitoring programs that the management entities use for summer Chinook in the U.S. and Canadian sections of the Okanagan River. The current escapement estimates will be reviewed relative to the CTC bilateral data standards for Chinook escapement indicator stocks. Any new escapement methodologies will be communicated to the OWG and other for review and feedback on study design recommendations that could help the management entities achieve these CTC data standards and summarize them for the Commission.*
    - ✓ A virtual workshop was held December 17, 2020. There were 18 participants from 9 management entities, with 3 presentations. The current escapement estimates were reviewed relative to the CTC bilateral data standards for Chinook escapement indicator stocks. New escapement methodologies were communicated to the OWG and others for review and feedback on study design recommendations that could help the management entities achieve these CTC data standards and summarized them for the Commission. A presentation was provided to the CIG during the PSC Annual Meeting in February 2021. A brief summary is in the Work Plan Comments section.
7. *A teleconference with the management entities and others will focus on the potential invasion of northern pike into the Okanagan River. The monitoring and control programs currently happening in the Columbia River upstream of Grand Coulee Dam will be reviewed, and advice will be sought from the management entities and other experts about the steps and methods to prevent the spread of northern pike into the Okanagan River. The findings and recommendations will be summarized for the Commission.*
    - ✓ A virtual workshop was held on April 21, 2021. The OWG was assisted by the Washington Invasive Species Council and the Washington Recreation and Conservation Office. There were 44 participants from 14 different entities,

with 6 presentations. The current monitoring and control programs in the Columbia River upstream of Grand Coulee Dam were reviewed, and advice was sought from the management entities and other experts about the steps and methods to prevent the spread of northern pike into the Okanagan River. A presentation is planned for the CIG as part of the new Work Plan Task 5. A brief summary is in the Work Plan Comments section.

Obstacles to Completing above Bi-lateral Tasks:

The extent and duration of the circumstances associated with COVID-19 was not anticipated, however for the next year the OWG will use remote teleconferencing approach to complete the tasks as necessary.

Outline of Other Panel / Committee Tasks or Emerging Issues:

At the 2019 Fall Meeting, the Commission identified that it will maintain the ad hoc Bilateral Okanagan Chinook Work Group, which will a) not be constituted under Article II of the Treaty; but will nonetheless b) provide an annual work plan for the Commission (initially in January 2020, and ongoing at the October Fall Meeting).

The OWG work plan tasks for this year are to continue the two annual tasks originally assigned by the PSC, one task that was not completed from the previous work plan, and a new task to produce a synthesis report of OWG activities since its last technical report published on the PSC website.

1. *Report escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through run year 2021.*

   This task will add another year of data collected by the management entities to the current analysis by the OWG.

2. *Conduct an exploitation rate analysis for Okanagan summer Chinook with CWT recovery data through 2020 and report the CWT statistics (e.g., mortality distribution tables, survival rates, maturation rates).*

   This task will add another year of data to the current analysis by the OWG.

3. *The Parties recognize the value of creating a baseline assessment of the current productivity and capacity of Okanagan River summer Chinook against which to measure the benefits of future habitat restoration and enhancement actions. The workgroup will coordinate a management entity exploration of alternative approaches to create such a baseline assessment. Alternatives may include a monitoring program for juvenile production, an analysis of spawner and recruit data, the use of habitat-based production models, or other approaches as appropriate.*

   A virtual workshop will be used identify and coordinate approaches in April 2022. This workshop will build on previous workshops hosted by the OWG.

4. *The OWG will develop a synthesis report to formally document hosted workshops, identify issues and impediments to Okanagan Chinook restoration, and recommended next steps.*

   The OWG anticipates meeting in-person in June 2022 to develop the synthesis report. The report will be an excellent resource for those involved with Okanagan Chinook and it will have helpful contextual information to facilitate discussions about Okanagan Chinook restoration and management.

5. *The OWG will develop and provide short presentations to the CIG with summaries of the findings and recommendations from the 3 recent workshops (Northern Pike, Survival, and Bilateral Supplementation Program).*

   The OWG anticipates providing these presentations to the CIG during November 2021 (Northern Pike-virtual meeting), January 2022 (Survival-PSC Post Season) and February 2022 (Bilateral Supplementation-PSC Annual). OWG participation is anticipated to be virtual unless the Post Season and Annual meetings are in person, and OWG members are present for other PSC panel and committee activities.

Potential Issues for Commissioners, including enhancement activities reported under Article V:

In-person meetings. Short virtual webinars will be used instead of in-person meetings, depending on the COVID-19 situation. Resources for the in-person synthesis report meeting could become an issue and the OWG requests that funding be provided by the national sections for travel and per diem costs.

Future role of OWG. The OWG intends to produce a synthesis report documenting work group activities, findings, and recommendations. Once complete, the Commission may want to discuss the need for an ongoing PSC role for in the restoration and management of Okanagan Chinook.

Potential Issues for Committee on Scientific Cooperation

None identified.

Proposed Meeting Dates and Draft Agendas:

Meeting	Dates	Location	Meeting Objectives
OWG-Task List Planning	Oct/Nov (TBD) 2021	Webinar	Outline more detailed plans to complete prioritized task(s) from Commission
OWG Northern Pike Update	Nov 2021	Webinar	Develop summary presentation for CIG on Northern Pike Workshop (Task 5)
OWG Survival Workshop Update	January 10-14 (PSC meeting)	Portland, OR	Develop summary presentation for CIG on Survival Workshop (Task 5)
Supplementation workshop Update	February 14-18 (PSC meeting)	Vancouver, BC	Develop summary presentation for CIG on Supplementation Workshop (Task 5)

Meeting	Dates	Location	Meeting Objectives
CWT Exploitation Rate Analysis	March	email	Task 2 analysis conducted during Chinook Technical Committee's Exploitation Rate Analysis
Escapement Reporting	March	email	Task 1 reporting
Baseline assessment workshop	April	Webinar	1 day virtual workshop regarding baseline for productivity and capacity approaches (Task 3), OWG conference calls and email to summarize findings and next steps
OWG Synthesis Reporting	June 20-22	Penticton, BC	Develop synthesis report for Commission (Task 4)
PSC Fall Session	October 17-21	Vancouver, BC	OWG co-chairs attend and present synthesis report findings and recommendations to Commission

Status of Technical or Annual Reports:

The OWG has not developed a report of its activities in 2020/2021 but plans to develop a synthesis report in the next cycle, which the OWG envisions as a Commission Technical Report. The OWG has produced summaries for three of the technical workshops and a summary for the most recent workshop is anticipated to be available in October 2021.

Comments:

Summaries for 3 of the 4 virtual workshops conducted during the last year are below.

Escapement

The current escapement programs applied in Canada and the US do not currently meet the CTC data standards for escapement estimates. Canada has initiated a new escapement program that relies on a PIT tag mark-recapture methodology that has been designed to achieve the CTC data standards. Several suggestions were provided to improve the quality of the US program, including ways to increase the accuracy of redd counts and the application of a transgenerational genetic mark-recapture methodology which has been used successfully by WDFW in Puget Sound and the Columbia River. The next steps involve discussion with CIG about funding options to improve the quality of the US escapement data to the CTC data standards, and implementing improvements to the US escapement program to achieve the CTC data standards.

Northern Pike

The potential invasion of northern pike is a serious risk to the productivity, abundance and fisheries for Okanagan and other Columbia River Chinook stocks. Currently, northern pike are found in the Columbia River and tributaries upstream of Grand Coulee Dam to Keenleyside Dam near Castlegar, BC. Invasion can happen via natural movements and dispersal, and from illegal fish stocking. Several case studies were examined where the impacts of northern pike were severe to the Chinook resource and fisheries, and the costs of the suppression programs were not only high, but ongoing for an indeterminate period since eradication is rare. Several preventative measures were identified, but funding for monitoring and response planning programs are key gaps that need attention. A bilateral response plan will be invaluable for agencies to prepare for and coordinate actions for the suppression, eradication and to restrict the spread of northern pike in the Okanagan when they are detected. The plan should include approaches for communication, media messaging, and potential funding opportunities. The plan should identify the permits necessary for suppression, to limit dispersal, and for eradication. The plan may involve a gap analysis component to acquire information that would be helpful to improve the response plan.

Survival

The survival of Okanagan Chinook in freshwater was examined at the egg-to-fry, juvenile rearing and smolt migration, and adult migration life stages. For each life stage, several factors were discussed that threaten survival, including habitat quality, the irrigation system, dam passage, predation and the effects of high water temperatures on Chinook behavior and survival. These factors were considered in terms of their geographic extent, persistence (i.e., temporal duration), and severity (i.e., mortality rate). Factors were weighted by their importance using the persistence and severity rankings from workshop participants, and geographic extent was applied as a multiplicative to the weight. Several knowledge gaps were identified along with suggestions for future investigations (i.e., studies on predation, sedimentation, and migration timing and delays). There were also several mitigation options identified to improve survival and Chinook abundance. In short, habitat restoration should be the highest priority to restore the Canadian Okanagan River to as natural of a state as practical (e.g., removal/modification of the antiquated VDS structures, reconnection with natural river channel, riparian restoration). There will be opportunities to restore and improve the habitat near the channelized sections in the Canadian Okanagan as the engineered channels have insufficient capacity for the river volumes modelled under climate change scenarios, and major modifications are necessary for water management.

PACIFIC SALMON COMMISSION WORK PLAN
[2022-2023]
October 3, 2022

Panel / Committee:

The Okanagan Working Group reports to the Pacific Salmon Commission.

Date: PSC Fall Meeting, October 17-21, 2022

Update on Bi-lateral Tasks Assigned Under Current PSC Agreement:

The Pacific Salmon Commission approved the following work plan tasks for the OWG in February 2022:

1) Report escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through run year 2021.

a. Data through run year 2021 have been provided and will be published along with prior years in the synthesis report described in Task 4.

2) Conduct an exploitation rate analysis for Okanagan summer Chinook with CWT recovery data through 2020 and report the CWT statistics (e.g. mortality distribution tables, survival rates, maturation rates).

a. Mortality distribution tables and CWT statistics have been updated through run year 2020. Mortality distribution tables for catch year 1992-2020 are discussed in the draft Synthesis Report (Sec. 4.4.3.4) and are displayed in one of the tables (Table 14). Survival rates (Release to Age 3 survival) are discussed in the draft report (Sec. 4.4.3.1) and listed in a table (Table 11). Maturation rates from brood year 1989-2017 are discussed the report (Sec. 4.4.3.2), and illustrated in a figure and listed in a table.

3) The Parties recognize the value of creating a baseline assessment of the current productivity and capacity of Okanagan River Summer Chinook against which to measure the benefits of future habitat restoration and enhancement actions. The workgroup will coordinate a management entity exploration of alternative approaches to create such a baseline assessment. Alternatives may include a monitoring program for juvenile production, an analysis of spawner and recruit data, the use of habitat-based production models, or other approaches as appropriate.

a. A baseline assessment workshop was held via webinar on April 21, 2022 with 25 participants. A summary of the workshop and the key findings are incorporated in a synthesis report that the OWG intends to finalize by the end of 2022.

4) The OWG will develop a synthesis report to formally document hosted workshops, identify issues and impediments to Okanagan Chinook restoration, and recommended next steps.

a. The OWG met in-person, with an option for virtual attendance, in Omak, Washington on June 22-24 to begin drafting the synthesis report, and held several follow up virtual meetings to continue progress. The workgroup expects to have a draft for initial review by the CIG when they meet next, likely in November 2022. Following CIG review, the OWG intends to finalize the report, and anticipates that it would be published as a PSC Technical Report in 2023.

5) The OWG will develop and provide short presentations to the CIG with summaries of the findings and recommendations from the 3 recent workshops (Northern Pike, Survival and Bilateral Supplementation Program).

a. The OWG provided a presentation to the CIG on February 15, 2022.

Obstacles to Completing above Bi-lateral Tasks:

The OWG has not encountered any obstacles to completing their assigned tasks for 2022 and is on track for delivering a first draft of the synthesis report (Task 4) for CIG review later this year.

Outline of Other Panel / Committee Tasks or Emerging Issues:

At the 2019 Fall Meeting, the Commission reviewed the OWG activities and results to date, and determined that it should continue to function as an ad hoc body rather than constituting it as a formal body, with the expectation that the OWG would be able to provide a comprehensive report to the Commission on the tasks that were initially assigned and then were updated, and sometimes expanded, in annual work plans. With the delivery of the OWG synthesis report, all of the assigned tasks have been completed, with the exception of Tasks 1 and 2 that are ongoing, as they are annual updates.

As the OWG has now provided the information and recommendations for which it was formed by the Commission, the OWG recommends the Commission consider the future of this ad hoc group. OWG members suggest that there are several different scenarios for the future of the OWG, including but not limited to, the following three:

- Disbanding the OWG, and assigning Tasks 1 and 2, which should be ongoing, to the Chinook Technical Committee.
- Maintaining the OWG as an ad hoc body of the Commission, and charging it with Tasks 1 and 2, and any other Tasks that are identified after the Synthesis Report is completed and discussed with the CIG. The OWG could provide annual reports to the Commission on the activities of the two countries that are relevant to the conservation and restoration of Okanagan Chinook spawning in Canadian waters and those identified in discussions with the CIG.
- Formalizing the OWG as a body of the Commission under Article II of the Treaty, and tasking it with compiling data on harvest and production of Okanagan Chinook, reporting annually to the Commission on its progress towards completing assignments, and drafting recommendations in support of conservation and restoration work for consideration by the Commission.

The OWG recognizes that the status of the working group can be a separate decision for the Commission from the future tasks, these are simply three examples of the type of decision in front of the Commission.

Potential Issues for Commissioners, including enhancement activities reported under Article V:

As described above, it will be timely for the Commission to determine whether it still has need of the OWG after it has the reviewed the Synthesis Report, and if so, to consider how it should be constituted and to provide new direction. If the Commission determines that the OWG should be continued, with new tasks, it may also want to consider whether additional parties or members should be added to the working group. At present, the list of contributors to the Synthesis Report includes staff from several agencies who were not officially listed in the OWG in the Terms of Reference. Staff from ADFG, ODFW and the Colville Tribes, and others from the Okanagan Nation Alliance and CDFO have all been active participants in the OWG for the last two+ years, longer in some cases, and have been key to the success of the OWG. They have participated in all of the workshops and are contributors to the Synthesis Report. The particular assistance of the Colville Tribes should be recognized; it has ranged from assisting with logistics for the two in-person meetings the OWG has held in the Okanagan watershed to providing data and analyses that have been critical to completing the tasks assigned by the Commission.

Potential Issues for Committee on Scientific Cooperation

The OWG is not aware of any issues that should be highlighted for the Committee at this time.

Proposed Meeting Dates and Draft Agendas:

The OWG anticipates a hybrid meeting to review the CIG comments on the draft report, likely in conjunction with the first PSC meeting following the CIG review. We anticipate that both co-chairs will attend in-person, and perhaps up to 2 additional people. The meeting duration would likely be 2 days or less, and use a small meeting room (<8 person capacity). OWG meetings after that would depend on the Tasks in the work plan a Commission decision regarding the future of the OWG, with an emphasis on meeting virtually.

Status of Technical or Annual Reports:

The Synthesis Report (Task 4) is on track for initial review by the CIG, likely in the last two months of this year, and then finalizing for Commission approval.

Comments:

None

PACIFIC SALMON COMMISSION UPDATES TO WORK PLAN
[2022-2023]
February 14, 2023

Panel / Committee: The Okanagan Working Group reports to the Pacific Salmon Commission.

Date: PSC Annual Meeting, February 2023

Update on Bi-lateral Tasks Assigned Under Current PSC Agreement:

The Pacific Salmon Commission approved the following work plan tasks for the OWG in February 2022:

1. Report escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through run year 2022.
    a. Data through run year 2022 have been provided and will be published along with prior years in the synthesis report described in Task 4.

2. Conduct an exploitation rate analysis for Okanagan summer Chinook with CWT recovery data through 2020 and report the CWT statistics (e.g., mortality distribution tables, survival rates, maturation rates).
    a. Mortality distribution tables and CWT statistics have been updated through run year 2020. Mortality distribution tables for catch years 1992-2020 are in the Summary of Findings and Considerations for Future Actions Report, along with survival rates (Release to Age 3 survival) and maturation rates (brood years 1989- 2017).

3. The Parties recognize the value of creating a baseline assessment of the current productivity and capacity of Okanagan River Summer Chinook against which to measure the benefits of future habitat restoration and enhancement actions. The workgroup will coordinate a management entity exploration of alternative approaches to create such a baseline assessment. Alternatives may include a monitoring program for juvenile production, an analysis of spawner and recruit data, the use of habitat-based production models, or other approaches as appropriate.
    a. A baseline assessment workshop was held via webinar on April 21, 2022 with 25 participants. A summary of the workshop and the key findings are incorporated in a synthesis report that the OWG intends to finalize by the end of 2022.

4. The OWG will develop a synthesis report to formally document hosted workshops, identify issues and impediments to Okanagan Chinook restoration, and recommended next steps.
    a. The OWG met in-person, with an option for virtual attendance, in Omak, Washington on June 22-24 to begin drafting the synthesis report, and held several follow up virtual meetings to continue progress. The workgroup expects to have a draft for initial review by the CIG when they meet next, likely in November 2022.

Following CIG review, the OWG intends to finalize the report, and anticipates that it would be published as a PSC Technical Report in 2023.

5. The OWG will develop and provide short presentations to the CIG with summaries of the findings and recommendations from the 3 recent workshops (Northern Pike, Survival and Bilateral Supplementation Program).
    a. The OWG provided a presentation to the CIG on February 15, 2022.

Obstacles to Completing above Bi-lateral Tasks:

The OWG has not encountered any obstacles to completing their assigned tasks for 2022 and is on track for delivering a first draft of the synthesis report (Task 4) for CIG review later this year.

Outline of Other Panel / Committee Tasks or Emerging Issues:

At the 2022 Fall Meeting, the Commission reviewed the OWG activities and results to date, and determined that it should continue to function as an ad hoc body rather than constituting it as a formal body, with the expectation that the OWG would be able to provide a comprehensive report to the Commission on its annual work plan tasks.

The OWG work plan tasks for this year are to continue the annual tasks originally assigned by the PSC and produce a synthesis report of OWG activities. At the PSC Annual Meeting, the 2022/23 work plan was adjusted to include a new task (#3) in addition to the annual tasks (#1 and #2), as follows:

1. Report escapement abundance estimates of hatchery- and natural-origin summer Chinook in the U.S. and Canadian sections of the Okanagan River through run year 2022 by age, origin (hatchery/natural), adipose fin status (clipped/unclipped), run year, and location (river/brood stock).
2. Conduct an exploitation rate analysis for Okanagan summer Chinook with CWT recovery data through 2020 and report the CWT statistics (e.g., mortality distribution tables, survival rates, maturation rates).
3. Track and report to the Commission the progress made by management entities on the recommendations from the 2023 Draft OWG Synthesis report (Summary of Findings and Considerations Future Actions). This potential, new task is responsive to a need identified by the OWG for a Commission role in tracking the progress made by the two nations in design and implementation of a bilateral supplementation program. This would entail meeting virtually and periodically, likely on an annual basis, to compile information on Chinook restoration activities in the Okanagan and assess progress for reporting back to the Commission.

Potential Issues for Commissioners, including enhancement activities reported under Article V:

If the Commission sees the need for a bilateral coordination body to assist the two nations in the design and implementation of a bilateral supplementation program the OWG could assume that role. At present, there is no bilateral body that has been established by the two nations to conduct a program of this nature. This function could be similar in nature to some aspects of the bilateral enhancement agreements in the Appendix to Chapter One that outline the Stikine and Taku Enhancement Production Plans, but with some new components (consideration of hatchery genetic management plans) and without some components of those plans. For instance, the performance audit and resultant allocation changes sections of those plans would not apply. This would be a larger workload, and require more frequent virtual meetings, particularly in the design phase, and might entail broadening the participation of the OWG to include representation from all of the entities with an active role in a bilateral supplementation program. Accomplishing this would be a multi-year, multi-staged process. The first steps, would be oriented towards program design, building on and learning from, ongoing supplementation efforts in the watershed. Later steps would be directed at scaling up the program from current levels to bilaterally agreed production objectives that were developed during the design stage.

Potential Issues for Committee on Scientific Cooperation

The OWG is not aware of any issues that should be highlighted for the Committee at this time.

Proposed Meeting Dates and Draft Agendas:

The OWG has scheduled a one-day virtual meeting in April 2023 to review the CIG comments on the draft report and compile the information necessary to complete Tasks 1 and 2.

Status of Technical or Annual Reports:

The Synthesis Report (Task 4) is on track for final review by the CIG, likely this fall, and then finalizing for Commission approval.

Comments:

None

APPENDIX E: ADDITIONAL DATA

Appendix E1. List of yearling Okanagan summer Chinook Coded-Wire Tag (CWT) codes used for the Exploitation Rate Analysis (ERA). Escapement recoveries in the total recoveries field have not been expanded for inter-dam loss.[1]

Tag Code	Brood Year	Release Site	Release Size	Total Recoveries
630759	1989	Similkameen Pond	116,821	2,978
635613	1989	Similkameen Pond	85,304	1,271
634417	1990	Similkameen Pond	367,207	971
634604	1991	Similkameen Pond	360,380	974
635148	1992	Similkameen Pond	124,751	11
635154	1992	Similkameen Pond	133,923	911
635155	1992	Similkameen Pond	132,213	744
635156	1992	Similkameen Pond	16,729	40
635315	1992	Similkameen Pond	129,574	562
635706	1993	Similkameen Pond	180,115	51
635708	1993	Similkameen Pond	191,059	67
635762	1994	Similkameen Pond	212,443	1,513
635534	1995	Similkameen Pond	180,813	902
635536	1995	Similkameen Pond	181,497	812
636051	1995	Similkameen Pond	206,736	1,083
630610	1997	Similkameen Pond	558,351	18,261
630469	1999	Similkameen Pond	583,317	2,764
630996	2000	Similkameen Pond	525,923	6,712
631978	2002	Similkameen Pond	244,792	1,940
632579	2003	Similkameen Pond	574,908	3,468
633168	2004	Similkameen Pond	286,106	5,694
633169	2004	Similkameen Pond	282,476	5,812
633594	2005	Similkameen Pond	272,123	1,515
633972	2006	Similkameen Pond	94,884	2,020
634182	2006	Similkameen Pond	501,849	10,519
633475	2007	Similkameen Pond	104,016	972
634365	2007	Similkameen Pond	98,664	768
634366	2007	Similkameen Pond	108,712	800
634392	2007	Similkameen Pond	193,541	1,529
634875	2008	Similkameen Pond	340,501	11,397
635371	2009	Similkameen Pond	254,651	3,289
635579	2009	Similkameen Pond	265,152	3,581
635582	2010	Similkameen Pond	41,106	757
635690	2010	Similkameen Pond	202,655	3,462
635691	2010	Similkameen Pond	190,821	3,448

Tag Code	Brood Year	Release Site	Release Size	Total Recoveries
635968	2010	Similkameen Pond	169,278	2,740
635680	2011	Similkameen Pond	206,700	6,653
636173	2011	Similkameen Pond	209,118	6,977
636174	2011	Similkameen Pond	207,049	6,793
636181	2012	Omak Pond	21,513	402
636182	2012	Omak Pond	22,572	419
636293	2012	Similkameen Pond	112,895	2,800
200111	2013	Omak Pond	127,132	1,114
200112	2013	Omak Pond	127,885	981
200113	2013	Similkameen Pond	98,163	886
200114	2013	Similkameen Pond	81,953	942
200118	2014	Similkameen Pond	147,476	1,903
200119	2014	Similkameen Pond	36,869	2,018
200120	2014	Omak Pond	213,508	1,847
200126	2015	Omak Pond	191,661	1,997
200127	2015	Similkameen Pond	76,731	1,662
200139	2016	Similkameen Pond	26,772	197
200140	2016	Omak Pond	68,926	682
200141	2016	Omak Pond	68,310	632
200142	2016	Omak Pond	68,515	516
200143	2016	Similkameen Pond	89,925	562
200144	2016	Similkameen Pond	89,925	651
200145	2016	Similkameen Pond	136,412	1,118
201703	2017	Omak Pond	82,484	212
201704	2017	Omak Pond	74,095	103
201705	2017	Omak Pond	76,426	188
201706	2017	Similkameen Pond	89,653	167
201707	2017	Similkameen Pond	90,878	164
201708	2017	Similkameen Pond	38,296	28

[1] 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.

Appendix E2. Release for yearling smolts to age 3 survival estimates by brood year. The last column in the table indicates whether all ages from this brood have completely returned as of 2020.

Brood Year	Survival	Brood Complete?
1989	0.085	Yes
1990	0.012	Yes
1991	0.015	Yes
1992	0.028	Yes
1993	0.002	Yes
1994	0.038	Yes
1995	0.031	Yes
1996		Yes
1997	0.114	Yes
1998		Yes
1999	0.019	Yes
2000	0.051	Yes
2001		Yes
2002	0.034	Yes
2003	0.026	Yes
2004	0.074	Yes
2005	0.019	Yes
2006	0.070	Yes
2007	0.025	Yes
2008	0.094	Yes
2009	0.042	Yes
2010	0.059	Yes
2011	0.117	Yes
2012	0.084	Yes
2013	0.029	Yes
2014	0.057	Yes
2015	0.049	No
2016	0.048	No
2017	0.005	No

Appendix E3. Maturation rates by age. The age 6 maturation rate is assumed to be 1.

Brood Year	**Age 3**	**Age 4**	**Age 5**
1989	0.007	0.104	0.677
1990	0.007	0.092	0.554
1991	0.026	0.170	0.669
1992	0.008	0.097	0.895
1993	0.010	0.286	0.698
1994	0.013	0.116	0.812
1995	0.011	0.081	0.909
1996	-	-	-
1997	0.030	0.273	0.935
1998	-	-	-
1999	0.013	0.064	0.650
2000	0.008	0.120	0.607
2001	-	-	-
2002	0.028	0.155	0.892
2003	0.015	0.254	0.922
2004	0.070	0.375	0.935
2005	0.071	0.196	0.937
2006	0.023	0.264	0.959
2007	0.031	0.177	0.844
2008	0.118	0.395	0.948
2009	0.046	0.266	0.887
2010	0.034	0.196	0.884
2011	0.055	0.316	0.887
2012	0.072	0.188	0.949
2013	0.135	0.521	0.946
2014	0.026	0.262	0.993
2015	0.019	0.346	0.924
2016	0.016	0.291	-
2017	0.061	-	-

Appendix E4. Ocean exploitation rates by landed catch (LC), incidental mortality (IM) and total mortality (LC + IM) estimates by brood year.

Brood Year	LC	IM	Total
1989	0.207	0.063	0.270
1990	0.150	0.073	0.222
1991	0.074	0.089	0.163
1992	0.077	0.028	0.105
1993	0.087	0.022	0.109
1994	0.118	0.022	0.140
1995	0.094	0.029	0.123
1996	-	-	-
1997	0.242	0.052	0.293
1998	-	-	-
1999	0.315	0.058	0.373
2000	0.320	0.063	0.383
2001	-	-	-
2002	0.208	0.044	0.252
2003	0.119	0.026	0.145
2004	0.152	0.046	0.197
2005	0.201	0.045	0.246
2006	0.181	0.044	0.225
2007	0.284	0.052	0.336
2008	0.246	0.057	0.302
2009	0.229	0.066	0.295
2010	0.229	0.041	0.270
2011	0.207	0.037	0.244
2012	0.203	0.054	0.257
2013	0.132	0.055	0.187
2014	0.092	0.040	0.132