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Science Advisory Report 2024/060

WILD SALMON POLICY STATUS, LIMIT REFERENCE POINT, AND CANDIDATE ESCAPEMENT GOALS FOR OKANAGAN SOCKEYE SALMON

Sockeye salmon spawners in the Okanagan River above Osoyoos Lake.

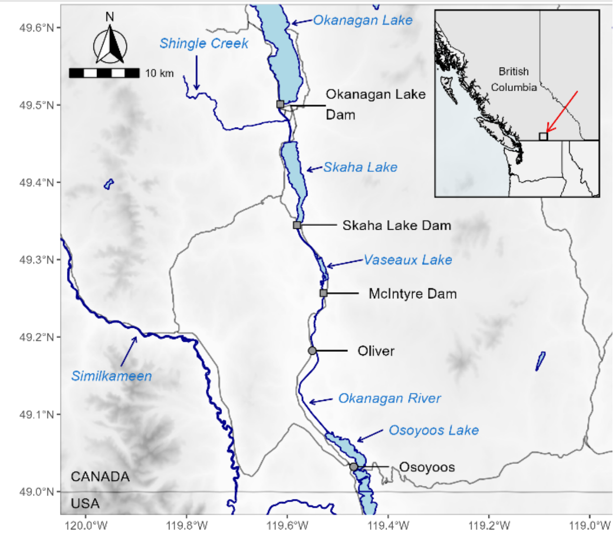


Figure 1. Okanagan basin, showing Osoyoos, Skaha and Okanagan lakes.

Context:

The Okanagan Sockeye salmon Stock Management Unit, comprised of one Conservation Unit, currently includes three populations rearing in Osoyoos, Skaha, and Okanagan nursery lakes. The current escapement goal of 35,500 was set in 1999, when only Osoyoos Lake was accessible. Hatchery-origin reintroductions from Osoyoos broodstock to Skaha and Okanagan lakes began in 2004 and 2016, respectively, and the Skaha lake population is now well established, accounting for almost half of total escapement in recent years (2019-2023 mean of 43.5% and range from 28.1% to 55.9%). Furthermore, since 1999, there have been substantial recovery initiatives in the Okanagan basin focused on improving overall salmon survival, including a water management system, spawning habitat remediation, and fish passage improvements. In 12 out of 20 years since 2004, escapements for the Osoyoos population alone have exceeded the current escapement goal, suggesting that the escapement goal from 1999 is no longer appropriate.

Fisheries and Oceans Canada (DFO) Fisheries Management Program has requested that Science Branch estimate the biological carrying capacity of the Okanagan system with respect to smolt production in the nursery lakes and total available adult spawning area in riverine habitats to determine appropriate escapement goals for Okanagan basin Sockeye salmon in British Columbia.

This Science Advisory Report is from the regional peer review of November 21-22, 2023 and June 25, 2024 on the Revised Escapement Goals for Okanagan Basin Sockeye Salmon in British Columbia. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

November 2024

SUMMARY

- Okanagan Sockeye salmon make up a single stock management unit (SMU), which contains a single conservation unit (CU) with three distinct spawning populations; these rear in Osoyoos Lake, Skaha Lake, and Okanagan Lake. Naturally returning spawners were re-established in Skaha Lake in 2011 and in Okanagan Lake in 2022, due to modifications to access barriers that allowed passage.
- The current escapement goal for Okanagan Sockeye salmon was set at 35,500 based on Hyatt and Rankin's (1999) study, but that target has since been exceeded in 12 of the past 20 years for the Osoyoos Lake population alone (2004-2023). Furthermore, improvements in water management, changes in stock assessment, habitat restoration, and range reintroduction due to improved fish passage have fundamentally changed the structure of, and our understanding of, the stock. Therefore, it no longer reflects the capacity of the habitats available to Sockeye salmon in the Okanagan basin.
- Estimates of current habitat capacity, and potential reference points, were explored using three alternative approaches: (1) spawning habitat capacity estimates based on detailed habitat mapping of flow and gravel sizes (all three lakes); (2) rearing habitat capacity estimates based on in-lake sampling (e.g., stomach contents) and food web modeling (Osoyoos and Skaha Lakes); and (3) estimating reference points based on spawner-recruit models (Osoyoos Lake).
- Estimates of spawning habitat capacity were found to be the most appropriate approach for determining population status and candidate management reference points, because consistent and reliable estimates could be developed for all three populations. Median spawning habitat capacity for all three populations combined ranged from 180,754 to 205,588.
- Wild Salmon Policy (WSP) status was evaluated for the combined spawner time series for Osoyoos and Skaha lakes, based on four standard metrics (relative abundance, absolute abundance, long-term trend and percent change over three generations) and associated benchmarks using established methods.
- The final status was assessed as Amber with high confidence. However, the CU faces serious threats from climate change and is at high risk of declining into Red status in the near future.
- The Okanagan Sockeye salmon SMU, which contains one CU that is not currently Red status, is considered to be above the Limit Reference Point (LRP) under the Fish Stock Provisions of the modernized Fisheries Act.
- Habitat-based estimates of the number of spawners that maximizes recruits (S_{MAX}; corresponding to full use of the available spawning habitat) for all three lakes were used to identify candidate management targets for the Okanagan Sockeye SMU. A candidate target range of 96,000-135,000 spawners would approximate an escapement goal based on S_{MSY} (as 50-70% S_{MAX}). A candidate target range of 192,000-231,000 spawners could be used to represent a goal of maximizing total production (100-120% S_{MAX}). Escapement goals specific to each lake population are also estimated and provided.
- Okanagan Sockeye salmon are already being impacted by climate change. Climate change effects will likely increase the frequency of adverse conditions throughout their lifecycle (e.g., thermal barriers during adult return migration, increased egg mortality due to freezing). Preserving diverse phenotypes may increase long-term resilience and should be considered as part of management planning.

INTRODUCTION

Canadian Okanagan Sockeye salmon are one of only three remaining Sockeye salmon stocks in the Columbia River basin, and on average (since 2008), account for more than 80% of all Sockeye salmon returning there (Hyatt and Stockwell 2019). Throughout history, the Columbia River has sustained substantial fisheries crucial to First Nations/Tribal communities. Following colonization, these waters have continued to support a diverse array of fisheries, including US commercial, Treaty Tribal, non-treaty, and Canadian First Nations fisheries. Historically, Sockeye salmon were present in Osoyoos, Skaha and Okanagan lakes (Fryer 1995), but dams erected in the twentieth century prevented access to the spawning grounds above Skaha and Okanagan lakes. In 2004, the first hatchery-origin Sockeye salmon fry were reintroduced upstream of Skaha Lake using Osoyoos Lake broodstock, and in 2011, the Skaha Lake outlet Dam was modified to allow passage of returning spawners. In 2016, hatchery-origin fry (also from Osoyoos Lake brood stock) were first reintroduced to the tributaries of Okanagan Lake (Hyatt et al. 2019), and in years 2020-2021, a small number of returning adults were allowed access to Okanagan Lake. In 2022-2023, spawners were allowed to pass freely into Okanagan Lake; just under 5,000 Sockeye salmon spawners were enumerated in the Okanagan Lake tributaries in 2022 and 14 in 2023. The latter year demonstrated poor escapement for the conservation unit as a whole, and presently there is only partial passage of adult Sockeye salmon into Okanagan Lake.

In addition to barrier passage modifications, Fisheries and Oceans Canada (DFO), the Province of British Columbia (BC), and the Okanagan Nation Alliance (ONA) have worked collaboratively on several initiatives that share an overall objective of improving salmon survival (Hyatt and Stockwell 2019). These projects include a water management system implemented since 2004 (Hyatt et al. 2015, Mathieu et al. 2023) and spawning habitat remediation (Carlile 2022). Overall, these initiatives have successfully supported larger spawner abundances and run sizes than any observed since the 1960s, and in 12 of the last 20 years since 2004 (inclusive), escapements for the Osoyoos population alone have exceeded the overall escapement goal of 35,500, which was set in 1999 based on contemporary understanding of Osoyoos Lake capacity (Hyatt and Rankin, 1999). These observations suggest that the escapement goal that has been in place since 1999 no longer represents the current population structure and potential for sockeye production.

The Okanagan Sockeye salmon Stock Management Unit (SMU) is comprised of three populations associated with Osoyoos, Skaha, and Okanagan nursery lakes. When the conservation unit (CU) under Canada’s Wild Salmon Policy (WSP) (DFO 2005) was first defined for this stock, only Osoyoos Lake was accessible, and it was therefore defined as “Osoyoos Sockeye salmon.” Following barrier modification and subsequent recolonization of Skaha and Okanagan lakes, the CU was revised in 2024 to include all three lake populations and renamed “Osoyoos-Skaha-Okanagan Sockeye salmon.”

DFO Fisheries Management has requested that Science Branch estimate the biological capacity of the Okanagan basin and propose updated escapement goals for Okanagan Sockeye salmon. The assessment and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform DFO Fisheries Management on the revisions to the harvest management and spawning escapement objectives. This biologically-based assessment will also be used to support bilateral discussions between Canada and the USA.

The three key objectives of this process are to:

1. Determine the status and Limit Reference Points (LRP) for the entire Okanagan basin Sockeye salmon SMU, or as separate lake populations for fisheries management purposes, if the data support it.
2. Derive Sockeye salmon spawning escapement goal(s) for the Okanagan basin as a whole, based on the results of (1).
3. Examine and identify uncertainties in the data and methods, including any relevant ecological and climate change considerations.

This document is intended to give fisheries managers relevant details of the biology of the stock, to support and inform its escapement goals. Consideration of socioeconomic objectives, cultural values, and also potential ecosystem factors from a possible future risk assessment, are beyond the scope of this process.

ASSESSMENT

We explored three alternative approaches to developing biologically-based candidate reference points:

1. biological carrying capacity of the system based on quantifying the spawning habitat capacities of the three nursery lakes (Osoyoos, Skaha, and Okanagan),
2. updated estimates of freshwater productivity in two of the rearing lakes (Osoyoos and Skaha), and
3. a spawner-recruitment (SR) model for the Osoyoos Lake population.

Additionally, the biological status of the Osoyoos-Skaha-Okanagan CU was assessed based on established metrics and benchmarks, while accounting for the range expansion of Sockeye salmon in the CU. Based on estimates of spawning habitat capacity, alternative management reference points, based on either approximating spawners at maximum sustainable yield, and spawners that S_{MSY} and spawners that maximize recruitment, S_{MAX} are presented for each lake separately, and also for the whole stock management unit containing all three lakes. Finally, uncertainties in the data and methods, as well as a discussion of the potential impacts of climate change on Okanagan Sockeye salmon and future work are presented in the CSAS Research Document.

Estimates of spawner numbers were available for all three lake populations: beginning in 1961 for the Osoyoos Lake population, 2012 for the Skaha Lake population, and 2022 for the Okanagan Lake population. While spawner-recruit modeling is usually the default method for determining reference points for Pacific salmon populations, a suitable time series for this type of analysis exists only for the Osoyoos Lake population. Therefore, other methods were explored in order to estimate reference points based on habitat-based carrying capacity, which can be calculated in the absence of an adequate spawner-recruit time series. Another benefit of these methods is that they provide candidate reference points that are based on the potential of each habitat, rather than on the current population abundance, which for Skaha and Okanagan lakes is still being supported by hatchery supplementation. Those lakes have available habitat that is presumably not yet fully colonized and thus have not reached their naturally self-sustaining abundance (as the Osoyoos Lake population likely has). Additionally, due to the short time series and lack of density-dependent reduction in recruitment over the observed range of spawner abundances for the Osoyoos population, the Bayesian spawner-recruit and spawner-smolt Ricker model fits were highly sensitive to alternative prior assumption about the capacity parameter. In a sensitivity test of nine alternative capacity prior specifications, the median posterior estimate of S_{MAX} for the Osoyoos Lake population ranged from 99,000 to

537,000 for spawner-adult Ricker fits and from 99,000 to 522,000 for spawner-smolt Ricker fits. Similarly, the median posterior estimate of S_{MSY} for the Osoyoos Lake population ranged from 66,000 to 300,000 for the spawner-adult Ricker fits.

The first of these habitat-based methods involves using fish length, redd area, spawning habitat area and bed particle (gravel) size to estimate spawning capacity. The data required for this method was recently updated for all three lake populations (Table 1). This is the only method that could be applied (at this time) to all three populations.

Table 1. Estimated spawning area and the spawner capacity estimated from two habitat-based methods for each lake population.

Population	**Available Spawning Area (m^2)**	**Spawning Capacity**	**Lake Rearing Capacity**
Osoyoos Lake	139,663	108,977	131,619
Skaha Lake	35,497	35,998	30,391
Okanagan Lake	50,243	49,569	Not available

The second habitat-based method aimed to estimate juvenile lake-rearing capacity. This method is much more data-intensive and required estimates of juvenile abundance, as well as broad biological sampling of the entire pelagic food webs. The data were available to apply this method to Osoyoos and Skaha Lakes over a short time period, but not for Okanagan Lake.

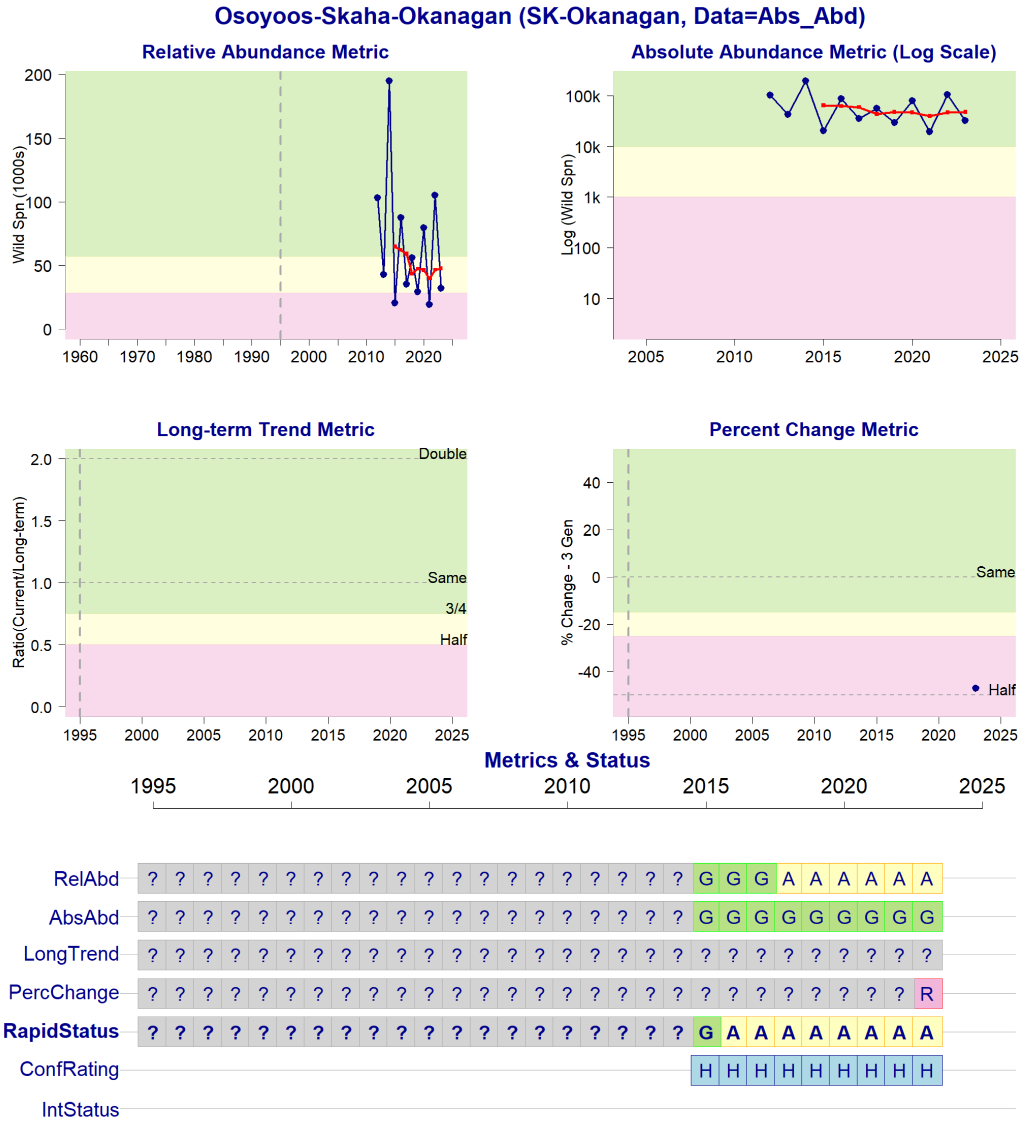
Based on the outcomes of these analyses, it was determined that estimates of spawning habitat capacity provided the best source for determining both biological benchmarks for status determination and candidate management reference points (i.e., escapement targets).

The WSP status for the CU was assessed as Amber with high confidence based on the combined spawner abundance for Osoyoos and Skaha lakes (Figure 3), which captures the vast majority of natural spawner abundance in the CU in recent years. This combined time series has consistent spawner estimates starting in 2012, so 2015 is the first available 4-yr generational average for status assessment.

Status was determined through expert review of the outputs of the Rapid Status Algorithm (Pestal et al. 2023, DFO 2024), which aimed to capture the outcomes of expert-driven integrated status assessments carried out in the past (Grant et al. 2011, Grant and Pestal 2013, Grant et al. 2020, DFO 2015, DFO 2016). Lower and upper benchmarks for the relative abundance metric were identified at 20% and 40% of estimated median spawner capacity, respectively (20% of habitat-based S_{MAX}: 28,603; 40% of habitat-based S_{MAX}: 57,207). The choice of using these benchmarks is consistent with previous status assessments for the Chilliwack-ES Sockeye salmon CU (Grant et al., 2020, p. 160). In addition to the relative abundance benchmarks defined above, the absolute abundance metric (with 1,000 and 10,000 as lower and upper benchmarks) is applicable, because the time series captures most of the current wild spawners in the CU. However, generational average spawner abundance has been well above 10,000, so this metric does not affect the status determination in this case. Due to the short time series for Osoyoos and Skaha combined, only one data point (2023) was available for the percent change metric, and long-term trend metrics were not available. These trend metrics do not affect the status determination in this case, because the trend metrics are not used in the WSP rapid status algorithm when the relative abundance metric is available. The WSP rapid status was Green only for the first year in the available time series of generational averages (2015). In all subsequent years, the status was consistently Amber, with High Confidence (2016-2023). The percent change metric (assessed only for 2023) identified a strong decline over the last 3 generations and falls into the *Red* status zone for this metric.

Even though the status for the whole CU has been Amber since 2016, harvests have been high and have averaged 64,254 (range 4,185 - 175,863), with many of the recent years experiencing harvest numbers and enroute mortality each greater than spawner abundances (Figures 4 and 5). Critically, even though the status for the whole CU has been Amber from 2016 to present (as based on the generational average spawner abundance), in some of those years (i.e., 2015, 2019, 2021, and 2023) the annual spawner abundance was below, or close to, the lower benchmark for the relative abundance metric. Major pressures that could push the CU into Red status in the near future are increases in water temperatures during adult upstream migration, high temperatures in Osoyoos Lake, as well as harvests and harvest-related mortalities. For these reasons, it is important for experts (ONA and DFO) to annually review the WSP rapid status assessment and work together to provide regular updates. Additionally, if a self-sustaining natural spawning population is fully established in Okanagan Lake, the time series used for status assessment should be reconsidered. It should be noted that the WSP rapid status assessments are a western science process that does not take into account Okanagan Nation’s more refined management practices and goals.

Recent science advice for determining limit reference points for SMUs under the Fish Stocks Provisions of the modernized Fisheries Act (C.A. Holt et al., 2023; K. Holt et al., 2023) recommended that LRPs be based on the status of the component CUs. It recommended that if any one CU in an SMU was determined to be in the Red zone, the entire SMU should be considered “below the LRP”. The Okanagan Sockeye salmon SMU includes only one CU which does not currently have Red status, and therefore this SMU is considered to be above the Limit Reference Point under the Fish Stock Provisions in DFO’s modernized *Fisheries Act* (2019).



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
RelAbd	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	G	G	G	A	A	A	A	A	A
AbsAbd	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	G	G	G	G	G	G	G	G	G
LongTrend	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
PercChange	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	R
RapidStatus	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**?**	**G**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
ConfRating																					H	H	H	H	H	H	H	H	H
IntStatus																													

Figure 2. Metrics and status for the Osoyoos-Skaha-Okanagan CU (SEL-01-01) using the combined spawner abundance of Osoyoos Lake and Skaha Lake as the status indicator. The combined time series starts in 2012, so the generational average used for status determination is first available in 2015. Top panels show the four standard WSP metrics, calculated based on the available time series of spawner abundances. The bottom panel summarizes the status for each individual metric and shows the resulting rapid status for the CU with a confidence rating. This CU was not previously assessed in an integrated WSP status assessment workshop, so the IntStatus row is empty.

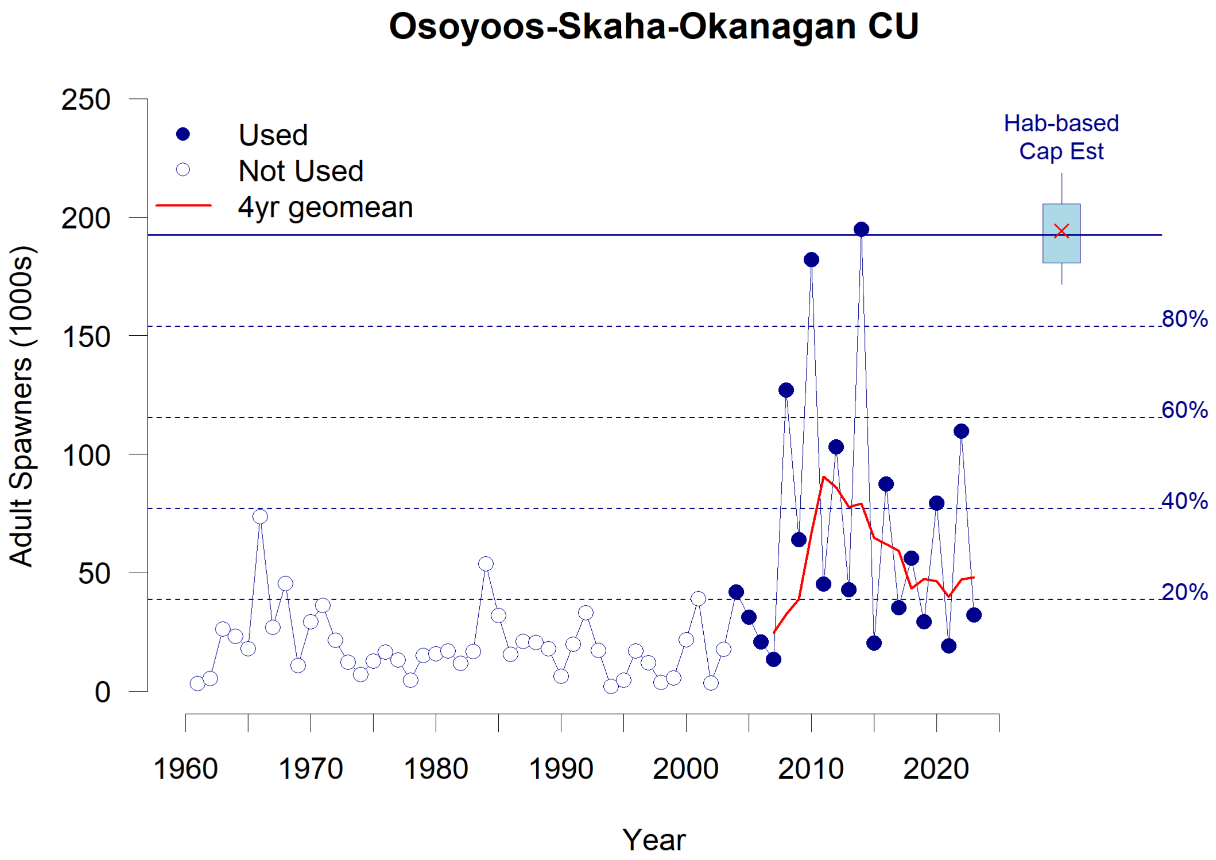


Figure 3. Spawner abundance compared to habitat-based estimate of spawning capacity – Osoyoos-Skaha-Okanagan Conservation Unit. The time series shows all available estimates, but only estimates starting in 2004 (solid circles) were used for status assessment. Values before 2011 include spawners from only the Osoyoos Lake population. Values from 2011 to 2021 include spawners from the Osoyoos Lake and Skaha Lake populations. Values starting in 2022 include spawners from the Osoyoos Lake, Skaha Lake, and Okanagan Lake populations. Please see Table 2 for candidate values based on other combinations of lake populations. This figure refers to the bottom row of that table. The red solid line represents the 4-year running geometric mean. The boxplot for habitat capacity shows the median (horizontal line), mean (red x), 25th and 75th percentiles (box), and 10th and 90th percentiles (whiskers). Horizontal dashed lines mark candidate benchmarks and targets defined in terms of the percentage of the median habitat-based spawning capacity estimates (secondary y-axis).

Given the ongoing range expansion and observed difference in the spawner trends for the Osoyoos and Skaha lake populations, candidate management reference points for all three lake populations are provided separately, as well as for the overall SMU. These are based on alternative proportions of the estimates of spawning habitat capacity, which is assumed to be a proxy for S_{MAX} (Table 2).

A target range to guide the identification of an escapement goal for each lake population could be based on an objective of maximum sustainable yield (MSY). With the available information, S_{MSY} could be approximated as 50% of the habitat-based S_{MAX}, given that 40% of S_{MAX} has been used to approximate 80% of S_{MSY} (Grant et al., 2020, 2011; Grant and Pestal, 2013), and the target range could span 10% on either side (i.e., 40% to 60% of the habitat-based S_{MAX}). Alternatively, a target range for each lake population could be set at 90% to 110% of the habitat-based S_{MAX} estimate, which would approximate an objective of maximizing total production. If managers require aggregated targets across lakes, it should be considered that these component populations will not covary uniformly, requiring higher targets than a simple sum of the targets from each lake. Identifying the level to which these targets would need to increase upon aggregation would require simulation analyses, which was outside the scope of this process; therefore, target proportions of identified reference point estimates (S_{MSY} and S_{MAX}) were simply increased by 10% in an attempt to capture this uncertainty. Considering the SMU as a whole, a candidate target range for an approximate S_{MSY} objective was identified as 96,000 to 135,000 spawners, and a candidate target based on S_{MAX} as between 192,000 to 231,000.

Table 2. Examples of candidate management reference points for Okanagan Sockeye salmon. Target ranges use alternative proportions of the median habitat-based S_{MAX} estimate, rounded to the nearest 1,000. For individual lakes, the approximate S_{MSY} target is set at 40% to 60% of habitat-based S_{MAX} estimates, and the S_{MAX} target is set at 90% to 110% of habitat-based S_{MAX}. For the overall SMU, higher percentage values are used to account for variable stock composition (50%-70% for S_{MSY}, 100%-120% for S_{MAX}). Note: the performance of these candidate targets has not been tested in forward simulations.

Population Unit	**S_{MSY} Target**	**S_{MAX} Target**
Osoyoos Lake	43,000 to 64,000	96,000 to 118,000
Skaha Lake	14,000 to 21,000	32,000 to 39,000
Okanagan Lake	19,000 to 29,000	43,000 to 53,000
All Okanagan Sockeye	96,000 to 135,000	192,000 to 231,000

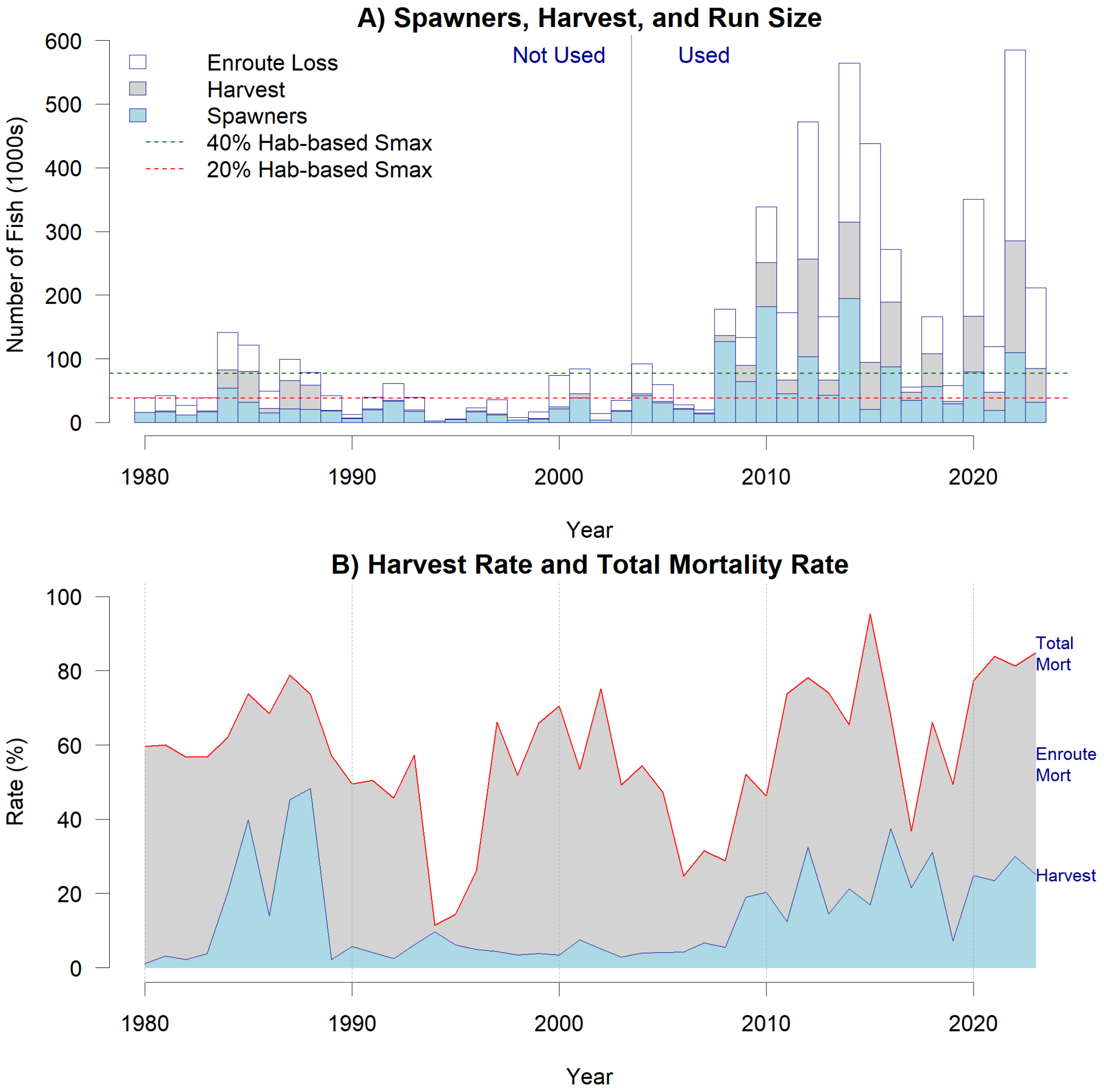


Figure 4. Summary of spawners, harvest, run size, harvest rate, and total mortality rate for the Osoyoos-Skaha-Okanagan Sockeye salmon CU. (A) Stacked bars show the annual proportion of the total run size that made it to the spawning grounds, was harvested in-river, or was assumed to have been lost during upstream migration to other sources of mortality. Annual spawner abundances can be compared to the habitat-based lower and upper benchmarks. (B) shaded areas show annual harvest rate and enroute mortality (freshwater only) components of the total mortality (red line).

Sources of Uncertainty due to Future Climate

Climate change, both current and future, poses a major threat to Okanagan Sockeye salmon throughout their lifecycle. During their upstream migration there are three key high temperature bottlenecks along the migration corridor of Okanagan Sockeye salmon that are likely to affect adult freshwater survival and productivity. These are:

1. the warmest reaches of the Columbia River mainstem, which are associated with the reservoirs behind Bonneville, John Day and McNary dams in the lower Columbia River;

2. the temperature in Pateros Lake (also called “Wells Pool” reservoir), which forms the Wells Dam forebay, where adult Sockeye salmon often hold before entering the Okanogan[1] watershed (Hyatt et al. 2003; 2020); and
3. the 115 km Okanogan River (WA), in which summer water temperatures are typically 3-5°C warmer than those in Pateros Lake (Hyatt et al., 2020; Stiff et al. (in prep.))[2].

Adult Sockeye salmon passage in the lower Columbia River is primarily concentrated between June and July. In June, mean daily water temperatures rarely exceed 18°C in the Bonneville forebay but rise to an average of 20 °C in July due to seasonal warming (Columbia River Data Access in Real Time (CBR-DART)). An analysis of the historical record shows that July water temperatures in the Lower Columbia River have increased by 2.6°C since 1949 (United States Environmental Protection Agency (USEPA), 2018). Increases in the frequency of dates with elevated thermal conditions of that magnitude are known to negatively affect migration speed, timing, fitness, spatial distribution, and disease profiles of migrating Sockeye salmon (Martins et al., 2012; Miller et al., 2014; Quinn et al., 1997).

Temperature-related impacts like these were most likely responsible for high mortality of adult Sockeye salmon in the Columbia River mainstem in 2015, when Bonneville temperatures in June were 3.4°C above the 10-year average. That year, 61% of the total run was exposed to temperatures greater than 20°C. In cool, wet years, the percentage of Sockeye salmon exposed to 20°C temperatures at Bonneville is on average 0.1% of the run (e.g., 1993, 1999, 2011, and 2012). The percentage typically increases to 10-20% in strong El Niño years (e.g., 1987, 1992, 1998) (CBR-DART).

Enroute mortality of upstream migrating adults is often higher than spawner numbers (Figure 5). In 2015, Sockeye salmon mortality between Bonneville and McNary dams was approximately twice as high as the multi-year mean recorded for 2006-2014 (Fryer et al. 2017), with mass die-offs of salmon recorded at multiple locations in the basin (NOAA 2016). A final estimate of the percentage of Okanagan-bound Sockeye salmon that reached the spawning grounds from the mouth of the Columbia River was less than 5% that year (Fryer et al. 2017; Hyatt et al. 2020). Statistically downscaled Global Climate Model (GCM) projections (Abatzoglou and Brown, 2012) of daily mean air temperature at key sites along the Okanogan/Okanagan River migration corridor (Hyatt et al. 2020) suggest that by 2040-2069, mortality events like the one in 2015 are likely to be more common.

Of the three rearing lakes, Osoyoos Lake is the most vulnerable to experiencing a temperature-oxygen “squeeze.” The temperature-oxygen squeeze occurs in summer when bottom oxygen concentrations fall below 4 ppm and the near-surface temperatures exceed 17°C. This squeezes the rearing juvenile Sockeye salmon into a small volume of suitable habitat within the water column (Brett et al., 1969; Brett and Blackburn, 1981). Uncertainty remains regarding whether interannual changes in the squeeze conditions would compromise juvenile Sockeye salmon growth and survival and contribute to declines in total returns. Future projections suggest that both climate-change induced reductions of river inflow and increased nutrient loading to Osoyoos Lake from human development will have negative impacts of unknown magnitude on Sockeye salmon returns (Hyatt et al. 2003; Merritt et al. 2006).

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[1] American portion of the Okanagan River

[2] Stiff, H.W., Hyatt, K.D., Stockwell, M.M., and Ogden, A.D. Trends in Water Temperature Exposure Indices for Adult Salmon Migration and Spawning in the Okanagan Watershed, 2010-2099. Can. Tech. Rep. Fish. Aquat. Sci. In prep.

Osoyoos-Skaha-Okanagan CU smolt outmigration occurs between April and June, with peak migration around mid-May. Climate change projections indicate that the mean frequency of dates in which mean daily water temperatures exceed 15 °C during outmigration could increase from 25-35 days (currently) to 41-45 days by the 2050s, mostly in May and June (Stiff et al in prep.)[2].

Finally, climate change may also lead to future impacts on the marine survival of Okanagan Sockeye salmon. Based on the findings of Hinch and Martins (2011), the majority of the Pacific Sockeye salmon stocks assessed are expected to see a possible decrease in the survival of immatures in the ocean and a very likely decrease in the survival of returning adults.

Sources of Uncertainty in the Data

Spawning capacity estimates were used in our analyses to determine status and candidate management reference points. However, estimates of spawning habitat capacity may be sensitive to model assumptions, such as the assumption that all fish are of the mean length observed in Osoyoos Lake. Monte Carlo simulations that randomly sampled known Sockeye salmon length ranges indicated that capacity estimates can vary substantially when variation in fish length is accounted for. This sensitivity analysis tests only for one assumption in the model. Thus, the model-estimated spawning capacities for the three lakes should be interpreted with caution, given that they are based on several assumptions, most of which have not been formally captured in our estimates of uncertainty. Furthermore, the spawning capacity estimates used in this paper to determine status and candidate management reference points represent a snapshot in time of a system that is undergoing range expansion and active restoration efforts.

The data used for the SR analyses were based on dam counts of returning adult Sockeye and dam count ratios, with adjustments for harvest. Such counts are imperfect for a number of different reasons. As many of these variables are typically unquantifiable, there remains some (possibly compounded) uncertainty in the net abundance of a given Sockeye salmon stock returning to the mouth of the Columbia River. Ascribing returning adults to a given lake in the Okanagan basin is an additional source of uncertainty in the SR analyses. Ratios of spawners, estimated using area under the curve, appearing on the Osoyoos and Skaha lake spawning grounds were used to apportion the relative numbers of Skaha- and Osoyoos-bound Sockeye salmon, although there was evidence of some straying between these two populations, estimated as 4% from only three years of relevant data. Also, estimates of Sockeye salmon spawner numbers in the Skaha Lake spawning areas were subject to misidentification of some Sockeye salmon as Kokanee salmon, or vice versa, particularly given that precocial Sockeye salmon spawners (“jacks”) can be misidentified as Kokanee salmon due to their smaller size relative to fully adult spawners.

The pre-smolt data that were used both for the Osoyoos Lake population SR analysis, and bioenergetics-based presmolt capacity estimates for Osoyoos and Skaha lakes, likely under-estimated the numbers of age-1 presmolts (i.e., juveniles staying in the lake for a second year) due to the ability of larger fish to evade the trawl net.

Finally, the bioenergetics analyses, which were used only as a way to corroborate the results of the spawner capacity estimates, were uncertain mainly due to the small number of years available for the study. As a result, there was only a single year in each of Osoyoos and Skaha lakes in which the capacity of the lake for juvenile Sockeye salmon seemed to be reached. Furthermore, it was unclear how generalizable those results are, especially given that in other years, larger numbers of juvenile Sockeye salmon were supported while carrying capacity did not appear to be reached.

CONCLUSIONS AND ADVICE

WSP status of the Osoyoos-Skaha-Okanagan CU has been consistently Amber since 2016, mainly driven by generational average spawner abundances falling between 20% and 40% of the habitat-based S_{MAX} estimate, used as the lower and upper relative abundance benchmarks, respectively. However, due to significant climate-related threats, there is a high risk of the CU's status declining to Red in the near future. It will therefore be extremely important to track its status annually and to rapidly identify any changes.

The habitat-based candidate target ranges presented here reflect contemporary and recent conditions in the Okanagan River basin and are therefore subject to future changes in the abundance and quality of available habitat. Furthermore, this SMU is currently undergoing substantial changes due to range expansion, spawning habitat improvements, hatchery-origin releases, and fluctuations in relation to ongoing variations in local climate, especially regarding increased temperatures, smaller snowpacks, and other changes in the timing of water inputs to the system. All of these influences demand that escapements and harvests be very carefully monitored each year by fisheries scientists and managers. Also, these instabilities make it difficult to advise on a specific number of years after which the next escapement goal review should occur. Instead, we recommend close annual attention to the characteristics of the SMU itself (e.g., exceeding escapement goals consistently, recolonization, spawning habitat capacity changes) to guide when it is appropriate to conduct the next escapement goal review, and when to organize discussions of this issue at the tripartite (ONA, DFO, and Province of BC) Canadian Okanagan Basin Technical Working Group (COBTWG) table.

In addition, given climate projections, managers should try to maintain genetic diversity (i.e., by maintaining healthy population sizes) in order to buffer against uncertain future climate conditions.

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