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Science Response 2018/052

SCIENCE INFORMATION TO SUPPORT CONSIDERATION OF RISKS TO CULTUS LAKE SOCKEYE SALMON IN 2018

Context

In 2003, Cultus Lake Sockeye Salmon (comprising the Cultus-L Conservation Unit (CU)) were assessed as *Endangered* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and recommended for listing under the *Species at Risk Act* (SARA). The *COSEWIC Endangered* recommendation has not changed in the most recent COSEWIC status assessment conducted in 2017. The Cultus-L CU was also placed in the Red status zone under the WSP in 2012, and remained in that status zone in 2018 when it was re-assessed. To date, this CU (which is referred to as a Designatable Unit (DU) by COSEWIC and SARA) has not been listed under SARA. Despite recovery efforts since 2000, the current abundance of Cultus Lake Sockeye Salmon remains at critically low levels and very poor returns are expected in 2018.

The Cultus Lake population is one of five CUs managed in the Late Run Fraser Sockeye Salmon management aggregate. This group enters the Fraser River and begins their annual upstream migration in August. In 2018, the Adams River stock (Shuswap Complex-L CU) (another component of the Late Run aggregate that is considered *Not At Risk* by COSEWIC) is expected to provide an abundant return of Sockeye Salmon. Although fishing plans for the 2018 season are currently under development, fishing opportunities on the Late Run aggregate are anticipated and, as a result, fishing mortalities of Cultus Sockeye Salmon are expected to occur. In some years, Fisheries and Oceans Canada (DFO) Fisheries Management has constrained fisheries on stronger stocks in order to protect weaker co-migrating stocks such as Cultus Lake Sockeye Salmon.

DFO Fisheries Management has requested that Science Branch provide an update of the state of knowledge for Cultus Lake Sockeye Salmon, with three specific objectives outlined in the Terms of Reference.

This Science Response Report results from the Science Response Process of July 18, 2018 on the review of Science Information to Inform Consideration of Risks to Cultus Lake Sockeye Salmon in 2018.

Background

Cultus Lake is a small (6.4 km^2) coastal lake in the lower Fraser River watershed that is the natal habitat of a unique population of Sockeye Salmon (Withler et al. 2000). While highly variable, the historical generational (four-year) average abundance of spawners entering the lake was about 20,000 fish prior to the 1980s (Figure 1). The Cultus Lake Sockeye Salmon population began to decline in the 1970s, and now has a generational average of about 1,000 spawners. It is suspected that high exploitation rates, particularly in the 1980s, contributed to the decline in abundance.

In the past decade, a variety of management, anthropogenic, and environmental factors may also be contributing to the current population status of Cultus Sockeye:

1. poor lake conditions affecting smolt/adult spawner survival (freshwater survival);
2. poor ocean conditions affecting adult/smolt survival (marine survival);
3. exploitation rates on dominant Adams years; note these exploitation rates are uncertain given the challenges of assessing exploitation on the low abundance Cultus stock, which are part of mixed stock fisheries of the more abundant Late Run stocks; and
4. elevated pre-spawn mortality affecting the number of effective female spawners (e.g., decreasing egg deposition).

Of the five co-migrating component CUs in the Late Run Fraser Sockeye Salmon aggregate, three are assessed as Endangered (Cultus Lake, Harrison Upstream- L, Seton-L), one as *Special Concern (*Lillooet-Harrison-L), and one as *Not At Risk* (Shuswap Complex-L) by COSEWIC. These assessments align with the most recent Wild Salmon Policy biological status assessments (three are Red, one is Amber and one is Amber-Green; DFO 2012; DFO 2018a). To date, none of the CUs (which are referred to as Designatable Units or DU's by COSEWIC and SARA) have been listed under SARA. There are further co-migrating stocks that have been assessed by COSEWIC as Endangered (e.g.) and Special Concern (e.g.) that are outside of the Late Run Fraser Sockeye Salmon aggregate, and are not in scope for this Science Response.

Beginning in 2000, a number of recovery actions were implemented to increase the abundance of Cultus Lake Sockeye Salmon, including: an ongoing Northern Pikeminnow removal program in the lake, an ongoing hatchery fish culture program that includes captive breeding (ended in 2013) and conventional supplementation (ongoing), Eurasian milfoil removal experiments and harvest reductions, under the guidance of the Cultus Sockeye Recovery Team (CSRT 2009), and Wild Salmon Policy (DFO 2005).

Since 2009, a number of changes have occurred in some of the science and enhancement programs which have implications for Cultus Lake Sockeye Salmon. For example, the DFO's Lakes Research Program has undertaken enhanced lake ecosystem monitoring (monthly limnology studies) of Cultus Lake, including multi-stage freshwater survival assessments to investigate mechanisms influencing juvenile freshwater survival. Also during this period, the Captive Broodstock Program was terminated in the 2013 brood year, which reduced the number of hatchery juveniles released into the lake and downstream of the lake by over 50% (i.e., from an average of 700,000 (2002-2012 brood years) to 300,000 (2013 to 2017 brood years).

The last comprehensive DFO assessment of Cultus Lake Sockeye Salmon (DFO 2010)—which indicated the decline may have halted—was completed prior to the termination of the captive brood program. The Cultus Lake population has not met the Conservation Objectives set by the CSRT, including Conservation Objective 4, which includes attaining a lower escapement benchmark of 15,000 wild spawners under the Wild Salmon Policy (DFO 2010; DFO 2018a). The assessment also projected that the population's long term viability would depend on the relative reproductive success of hatchery fish in the natural environment—a high priority information need that could inform significant changes to the enhancement program (DFO 2010).

This Science Response aims to summarize the available data and information to help inform Fisheries Management decisions for Fraser River fisheries in 2018.

Analysis and Response

The following is a synthesis of the data and information that is provided annually through the comprehensive pre-season forecast for Fraser River Sockeye Salmon (e.g., see DFO 2018b).

Spawner Abundance

The abundance of Cultus Sockeye Salmon spawners has been variable throughout the time series but has shown dramatic declines since the 1970s (Figure 1). The 2018 median return forecast for Cultus Sockeye Salmon is very low (1,000 spawners), in part due to the persistence of poor marine conditions (e.g., warm surface water temperatures; DFO 2018b).

Hatchery activities began with broodstock collection in 2000; the first adult return of hatchery releases was observed in 2005 (Figure 2). Hatchery returns have represented a significant proportion of the total adult escapement since 2008, ranging from 35% to 96% (Figure 2). Despite significant hatchery supplementation, total adult escapements (both natural- and hatchery-origin spawners) have dramatically declined since 2012 (Figure 3).

Survival

Smolt to adult survival is related to lake and freshwater conditions, early marine influences in estuarine / Strait of Georgia environments, ocean conditions, hatchery influences, and harvesting.

The production of natural-origin smolts from spawners that were passed into the lake is highly variable, but has been extremely low in five of the seven years since 2010 (Figure 4). Poor smolt production is a result of pre-spawning mortality of adults, and mortality during the egg, alevin and fry/parr stages.

Marked fry-to-smolt survival in Cultus Lake has declined dramatically since 2009 with the lowest survivals on record observed in each of the last three years (Figure 5).

The total number of smolts (natural- and hatchery-origin) leaving Cultus Lake in the last three years (2016-2018) are the lowest since significant hatchery supplementation began (Figure 6). A combination of a low number of smolts, and high sea-surface temperatures used in forecast models, contributed to the low number of returns expected in 2018, as well as 2019 and 2020.

Not accounting for variable harvest impacts (exploitation rates have ranged from 3% - 71% since 2005; Table 1), total survival from smolt-to-adult escapement (marked and unmarked combined) has averaged 1.2% since 2005; unmarked smolts have the highest survival rates averaging 3.3%, followed by smolts arising from hatchery fry releases averaging 1.7%; marked hatchery smolt releases have the lowest survival rates, averaging 0.6% (Figure 7). Note that in Figure 7, estimates of survival for unmarked smolts for 2010 and 2014 are based on small sample sizes and are more uncertain than similar estimates for other years.

Calculation of exploitation rate estimates for Cultus Sockeye Salmon are challenging due to the relatively low abundance of Cultus Sockeye (i.e., less than 20,000) compared to co-migrating Summer (2-5 million) and Late Run (600,000-9 million) populations. Small numbers of Cultus fish make them rare occurrences in DNA results, resulting in Cultus Sockeye Salmon likely being under-represented in stock composition data. Indirect estimates of exploitation rates through proxy stocks are problematic due to differences in migration timing and speeds.

Evaluation of Recovery Activities and New Information

An initial assessment of the recovery initiatives undertaken since the original COSEWIC assessment was reviewed in 2009 (DFO 2010). An update of this work will be part of the longer term Recovery Potential Assessment process for Fraser River Sockeye Salmon DUs that have been assessed as Endangered or Threatened (including the Cultus Lake DU), targeted for completion in March 2019. A Recovery Potential Assessment is used to provide science advice to inform a listing recommendation under SARA, and can also be used to inform management decisions if the species is not listed under SARA.

As the critical natal freshwater habitat for Cultus Lake Sockeye Salmon, habitat quality within Cultus Lake is potentially strongly influential upon survival at multiple life stages from egg deposition through smolt outmigration (Burgner 1991). Shortreed (2007) compared select limnological data taken in the 1920's-1930's with those from 2001-2003 and found that both biological productivity and surface water temperatures had increased through the 20th century, highlighting anthropogenic nutrient loading (i.e. cultural eutrophication) and climate change as the most parsimonious forcings.

Recent investigations appear to corroborate the inferences of Shortreed (2007), and preliminary results suggest that habitat conditions in Cultus Lake appear to have undergone further degradation since at least 2010, and likely limit current production of both natural- and hatchery-origin Cultus Lake Sockeye Salmon, a situation that is unlikely to ameliorate without mitigation efforts targeting nutrient enrichment (Putt 2014). Eutrophication of lakes is a reversible phenomenon with action (Smith and Schindler 2009), and is essential in systems where climate variability and/or change strongly influence lake ecology, such as appears to be the case for Cultus Lake (Shortreed 2007), as excess nutrient loads enhance the reactivity of lake ecosystem structure and functioning to climatic forcings (Moss et al. 2011). Abatement of nutrient loads to Cultus Lake is likely attainable with targeted effort, but is an interjurisdictional issue, requiring multiple stakeholder and governmental engagement to reduce nutrient loading from both the watershed and the atmosphere (Putt 2014).

In addition to annual operation of the Cultus Lake fence to evaluate population trends, sub-annual multi-life-stage hydroacoustic-trawl surveys (i.e., freshwater abundance and survival estimation at multiple stages), detailed monthly limnological monitoring (i.e. trophic ecology, habitat quality assessment), and targeted studies focusing on the influence, prediction, and potential mitigation of first order drivers of critical habitat and survival changes, led by DFO's Lakes Research Program, are ongoing. Currently, limnological and juvenile salmon survival studies are focussed on the seasonal biological productivity within Cultus Lake, its links to nutrient loading from a variety of sources and the interactive forcings of climate variability and change, which together are likely responsible for the emergence of late-season hypoxia to anoxia in deep-water habitats used by juvenile Cultus Lake Sockeye Salmon.

Enhancement of the Cultus Lake sockeye population has been conducted since 2000 to conserve genetic diversity in the population during the period of low abundance. Genetic analysis using microsatellite loci, conducted on Cultus Lake sockeye smolts and adults sampled at the Sweltzer Creek fence, indicates that the pre-enhancement level of genetic diversity has been retained throughout the enhancement period. The inclusion of naturally-spawned fish in the broodstock is a key measure employed to maintain adaptation to the wild environment in an enhanced population. Naturally-spawned fish have been included in the Cultus sockeye hatchery broodstock since inception of enhancement. Both population-level analysis (of gene frequencies) and the assignment of naturally-spawned smolts back to their parents (parentage-based-tagging) indicate that hatchery-origin fish have successfully spawned in Cultus Lake and contributed to smolt emigration and subsequent adult escapements.

The PNI (proportionate natural influence) values for the Cultus Lake sockeye population have averaged less than 0.5 over the period of enhancement (as expected in a conservation enhancement program) but were close to or exceeded 0.5 in 2013, 2014 and 2017. The majority of hatchery-origin fish have been released into Cultus Lake as fry and experienced survival rates that are similar to (or lower than) naturally-spawned fish. Therefore, the population has not been 'swamped' by hatchery production and the genetic influence of naturally-spawned fish in the population has likely been sufficient to maintain adaptation for natural spawning.

Additional Science advice is also being requested to inform the enhancement component of the Cultus Lake Sockeye Salmon conservation plan, in both the short and long term. In the short term, this will include advice on the most appropriate approaches for the management of the current hatchery program (i.e., breeding and release strategies) and in the longer term it should include the articulation of objectives of the hatchery program in the context of the broader strategy for the management of this CU given a new analysis of threats to recovery and likely outcomes of all recovery actions (i.e., goals for the population and management triggers for starting, changing and halting the enhancement program). This work is also targeted for inclusion in the longer term Recovery Potential Assessment process for Fraser River Sockeye Salmon planned for completion in March 2019.

Exploitation Rates

Cultus Sockeye Salmon and Fraser River Sockeye Salmon have been managed in an intensive, integrated international and domestic system for over half a century. The Cultus population is small relative to co-migrating populations such as Late Shuswap and Weaver. The Cultus population is managed as part of the larger Late Run aggregate to achieve escapement and catch objectives for the dominant and sub-dominant Late Shuswap stock on the 2017 and 2018 cycle lines and other populations such as Weaver on the 2015 and 2016 cycle lines (COSEWIC 2003).

During the late 1990s, annual exploitation rates on Late Run Sockeye Salmon were generally reduced as a result of management actions taken to address the change in behaviour of these populations (COSEWIC 2003 – Figure 11 and Table 3) – namely, an earlier upstream migration due to reduced holding period in the Gulf of Georgia. Cultus Sockeye Salmon exploitation, therefore, generally decreased post-1990, depending on the year. This change in behaviour was observed starting in 1996, when Late Run Fraser Sockeye Salmon began entering the Fraser River immediately upon arriving at the mouth of the river, rather than exhibiting their traditional behaviour of holding in the Gulf of Georgia for three to six weeks prior to beginning their upstream migration. This change in behavior persists and is associated with significant "en route" mortality (evidenced by differences in the numbers of fish estimated to have passed the Mission hydroacoustics site and those that are estimated to reach the spawning grounds, after catch is taken into account.See Cooke et al [2004] for a full description).

Due to the very low abundance of Cultus Lake sockeye in recent years, estimates of Cultus Sockeye exploitation rates are highly uncertain. Three sets of exploitation rate estimates are presented in Table 1. The fact that three sets of plausible exploitation rates can be generated highlights that the estimates are dependent on the data available at the time and can be highly variable. Confidence intervals are not available but would capture the further uncertainty associated with each point estimate. The discrepancies identified here raise the importance of undertaking further work to ensure that clear and consistent methodologies for calculating exploitation rate estimates are developed.

The first estimate is final in-season exploitation rate estimates, which are based on preliminary post-season catch and run size estimates for the more abundant co-migrating Late Run sockeye stocks which are used as an exploitation rate proxy for Cultus (Table 1, Column B). Given the uncertainty associated with estimating Cultus run size and catch, using similarly timed stocks as a proxy was the in-season method adopted by the Pacific Salmon Commission to estimate Cultus exploitation.

After further data are compiled and analyses conducted, two post-season exploitation rate estimates are provided (Table 1, Columns C and D). The first uses the same proxy stocks as the in-season estimates but also includes run size adjustments (RSAs) for years 2009-2015 (2016 and 2017 currently unavailable) (Table 1 Column C). Since 2009 the post season exploitation rates account for alternate estimates of en-route mortality in the calculation of total return through a review of the available environmental (i.e. temperature and discharge exposure) and biological (fish condition, behaviour, fishing pressure etc.) information. The third post season exploitation rate estimate includes the RSAs (Table 1 Column D); this estimate has been used in recent Fraser Sockeye Salmon status processes (DFO 2018a) and forecast processes (DFO 2018b).

Following the 2003 COSEWIC emergency listing of Cultus Lake Sockeye Salmon (COSEWIC 2003), the pre-season allowable exploitation rate was established at 10 to 12% for 2004 and 2005 (Table 1, Column A). The allowable pre-season exploitation rate was exceeded in 2004 at 26% but was met in 2005, with estimates ranging from 10%-12% (Table 1). Beginning in 2006, pre-season allowable exploitation rates on Cultus Lake Sockeye Salmon were increased to 20% to 30% (depending on the estimated Late Run run size), owing to improvements in Cultus Sockeye Salmon abundances. From 2006 to 2009, exploitation rate estimates were near or below pre-season allowable levels ranging from 3% to 35% (Table 1). In 2010 and 2014 (dominant Late Shuswap return years), allowable exploitation rates were permitted to increase above 30%, to match the Late Run exploitation rate, or the level where the Cultus Lake Conservation Objectives (CSRT 2009) 1 and 2 were being achieved, whichever was lower.

Given data uncertainties as described, the evidence still indicates that none of the Cultus Conservation Objectives have been met since the development of the Conservation Plan in 2009 (Table 2). Exploitation rates may have exceeded allowable levels in 2010 (estimates ranging from 37% to 50%; Table 1) as the exploitation rate was increased in-season to 43% following consultation with First Nations and stakeholders due to an unexpected large return of Late Run Fraser Sockeye Salmon. Since 2011, exploitation rates exceeded target levels in 2011, 2012, 2014 and 2016; and fell below target levels in 2013 and 2015 (Table 1).

Uncertainties and Other Factors

This review presented an opportunity to identify a number of key uncertainties and other factors for consideration of risks to Cultus Lake Sockeye Salmon. In particular, mechanisms pertaining to lake recovery have been identified and are currently being assessed. Although these may or may not pertain specifically to Cultus Lake Sockeye Salmon, they could nevertheless be beneficial to recovery of Sockeye Salmon in Cultus Lake.

Additionally, compilation of historical exploitation rate data highlighted uncertainties around the methods used to calculate the estimates of exploitation rates in the post-season. Additional resourced work is required to verify the underlying assumptions and data filters associated with each method to resolve the observed differences.

Finally, a number of recommendations were made as a result of the review in 2009 (DFO 2010), many of which are still relevant to the situation in Cultus Lake today. It is recommended that efforts be taken to assess and update the current role of enhancement and other mitigation strategies originally identified by the CSRT, particularly in light of new information emerging on the Cultus Lake ecosystem and anthropogenic influences on it.

Conclusions

If current survival trends continue, there is a high probability that less than 1,000 Sockeye Salmon will escape to Cultus Lake in 2018, particularly with increased fishing mortality on the Late Run timing group. At this time, the Cultus Sockeye Salmon population is not considered to be self-sustaining in the natural environment without targeted mitigation of factors limiting population persistence. Recovery of the wild population is only feasible if the cause of poor survival of Cultus Sockeye Salmon can be identified and mitigated. For example leading indicators, and the context from other systems suggest that lake recovery is achievable with appropriate land use management in the Cultus Lake watershed, aimed at reversing ongoing deterioration of water quality and salmon habitat, and the reduction of nutrient loading to decrease eutrophication.

The Cultus Sockeye Salmon population is not currently a 'wild' population given the history of conservation enhancement, but the level of natural influence in the population indicates that the population contains sufficient diversity and adaptation to return to a self-sustaining wild state given favourable environmental conditions and appropriate management actions to support juvenile production and adult escapement. The ongoing escapement of naturally-spawned fish to the population, even at low abundance, is important for maintaining adaptation to the natural environment.

The Department has committed to utilizing the precautionary approach, recognizing that in the absence of scientific certainty, conservation measures can and should be taken when there is knowledge of a risk of serious or irreversible harm to the environment and/or resources. The use of this approach is prevalent in stock management approaches such as the harvest decision making framework (DFO 2009), and is relevant in this case, where there is a recognized but not fully understood series of threats to the Cultus Sockeye population. The influence and interaction of harvest management, habitat degradation, past and current hatchery enhancement, and perhaps other factors are still under investigation.

Despite the Cultus Lake Sockeye Recovery Plan the abundance of the Cultus Sockeye Salmon population has continued to decline over time. It is recommended that the plan be re-evaluated to ensure it remains relevant and appropriate in light of recent environmental and management changes. This may include an immediate review of threats to the population and current recovery and management strategies, and an assessment of the recovery potential of this DU. Additional work is also needed to determine the role of hatchery supplementation in the context of recovery planning for salmon populations like Cultus Lake Sockeye Salmon, and targeted research to understand the mechanisms of their decline.

In general, a strategy that ensures appropriate review of prioritization and integration of the status of stocks, development of recovery plans, review of recovery actions and gaps, and monitoring of recovery activities, is recommended to support recovery of the Cultus Lake Sockeye Salmon population, and other salmon populations that are also currently at risk.

Tables

Table 1. Summary of pre-season allowable Cultus exploitation rates, final in-season exploitation rate estimates (using similarly timed Late Run stocks as a proxy), post season exploitation rate estimates using similarly timed Late Run proxy stocks (includes post season Run Size Adjustments from 2009-2015) and post-season Cultus exploitation rate estimates (includes Run Size Adjustments from 2009-2017). Late Run dominant years are shaded grey in the table and contain a 'd' superscipt.

Year	Column A	Column B	Column C	Column D

	Pre-Season Allowable Cultus ER [1]	Final In-Season ER[2] (Proxy)	Post Season Cultus ER[3] (Proxy)	Post-Season Cultus ER[4] (Direct)
2004	10-12%	26%	26%	26%
2005	10-12%	10%	11%	12%
2006[d]	25-30%	35%	35%	25%
2007	20%	14%	14%	16%
2008	20%	14%	14%	14%
2009	20%	3%	5%	5%
2010[d]	20-30%	37%	50%	50%
2011	20-30%	21%	34%	41%
2012	20-30%	18%	42%	47%
2013	20-30%	7%	5%	3%
2014[d]	20-30% or up to Late Run ER (56%)	55%	59%	71%
2015	20-30%	5%	10%	12%
2016	20%	11%	NA	22%
2017	20-30%	3%	NA	5%

Table 2. Summary of Cultus Conservation Objectives (CSRT 2009) to achieve the following goal: to halt the decline of the Cultus sockeye population and to return it to the status of a viable, self-sustaining and genetically robust wild population that will contribute to its ecosystems and have the potential to support sustainable use.

Objective No.	Objective (CSRT 2009 page)	Results to Date
1	Ensure the genetic integrity of the population by exceeding a four-year arithmetic mean of 1,000 successful adult spawners with no fewer than 500 successful adult spawners on any	**Not achieved:** Spawner success is associated with uncertainty; if estimates from the fence program are applied a number of years post-2009 fall below 500

[1] The annual allowable exploitation rate objectives are stated in DFO's annual South Coast Integrated Fisheries Management Plan (IFMP) document. Following in-season consultations with First Nations and other harvesters the 2010 pre-season objective was increased in-season to 43% given the unexpected large return of Fraser sockeye and Cultus sockeye escapement.

[2] Final in-season exploitation estimates based on preliminary post-season catch and run-size estimates. Alaskan catch was included in years 2004-2006, 2014 and 2015. Post season run size adjustments (RSAs) are not included. Due to the small contribution of Cultus Lake Sockeye Salmon relative to other Late Run stocks, similar timed Late Run stocks are used as a proxy to estimate the Cultus exploitation rate (all Late Run stocks excluding Birkenhead and Harrison).

[3] Preliminary post season exploitation estimates based on post-season catch and run-size estimates. Alaskan catch is included for all years. Due to the small contribution of Cultus Lake Sockeye Salmon relative to other Late Run stocks, similar timed Late Run stocks are used as a proxy to estimate the Cultus exploitation rate (all Late Run stocks excluding Birkenhead and Harrison). Estimates since 2009 include run size adjustments (RSAs) to account for estimates of en-route mortality (2016 and 2017 not are not available at this time).

[4] Preliminary post-season exploitation estimates based on a post season review of stock specific catch, escapement and total return. Estimates since 2009 include run size adjustments (RSAs) to account for estimates of en-route mortality. These estimates are used in recent DFO science processes (DFO 2018 a & b).

Objective No.	Objective (CSRT 2009 page)	Results to Date
	one cycle. (p. 25)	successful spawners, and there are years where a four year average falls below 1,000; this objective has not been met, therefore, throughout the recent time series
2	Ensure growth of the successful adult spawner population for each generation (that is, across four years relative to the previous four years), and on each cycle (relative to its brood year) for not less than three out of four consecutive years. (p. 25)	**Not achieved**. The growth target and timeline have not been completed to evaluate this; the population has decreased in two generations recently in 2014, 2015, and 2017;
3	Rebuild the population to the level of abundance at which it can be de-listed (i.e., designated *Not at Risk*) by COSEWIC. (p. 25)	**Not achieved**. Assessments to date: • *Endangered* by COSEWIC (2003; 2018) • WSP Red Status zone (2012; 2018)
4	Over the long term, rebuild the population to a level of abundance (beyond that of Objective 3) that will support ecosystem function and sustainable use. (p. 26)	**Not achievable** until Objective 3 is achieved; this also includes consideration of the WSP lower benchmark of 15,000 wild spawners, which has not been achieved.

Figures

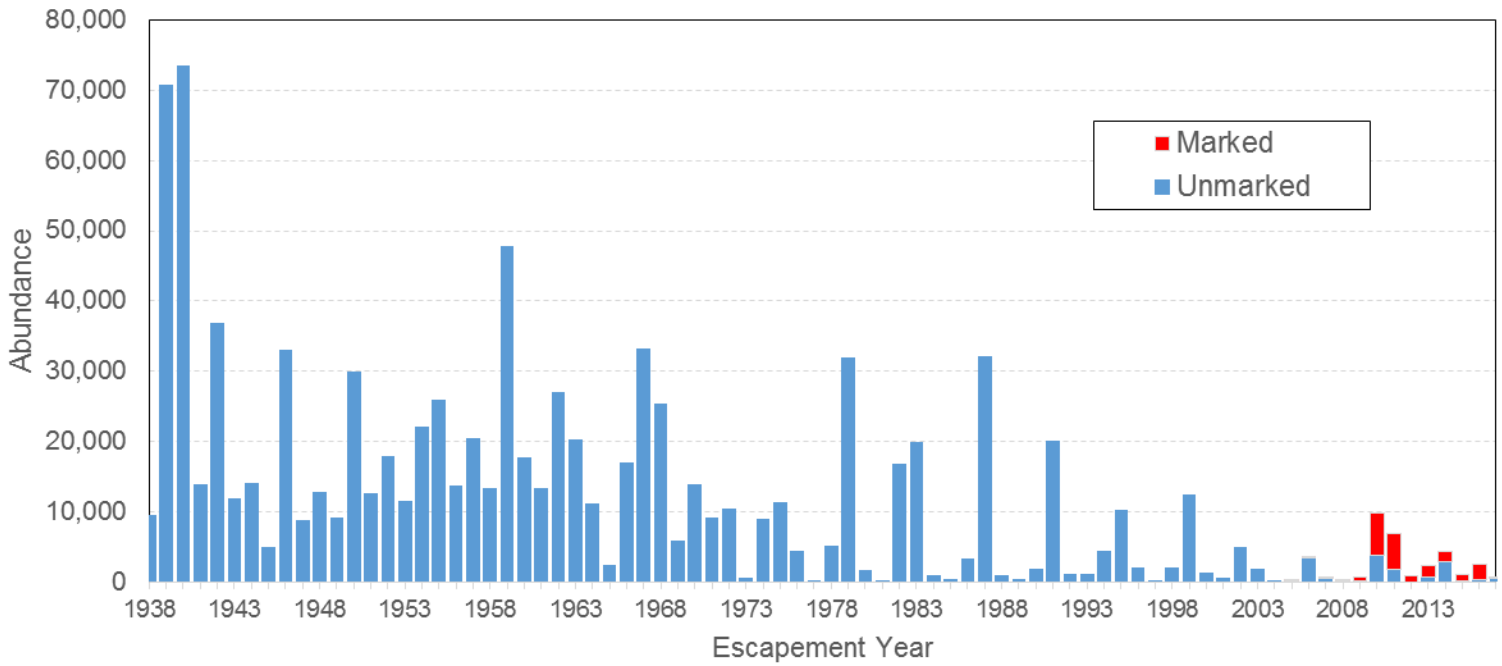

Figure 1. Annual historical Cultus Lake Sockeye Salmon adult escapements (including broodstock), 1938-2017.

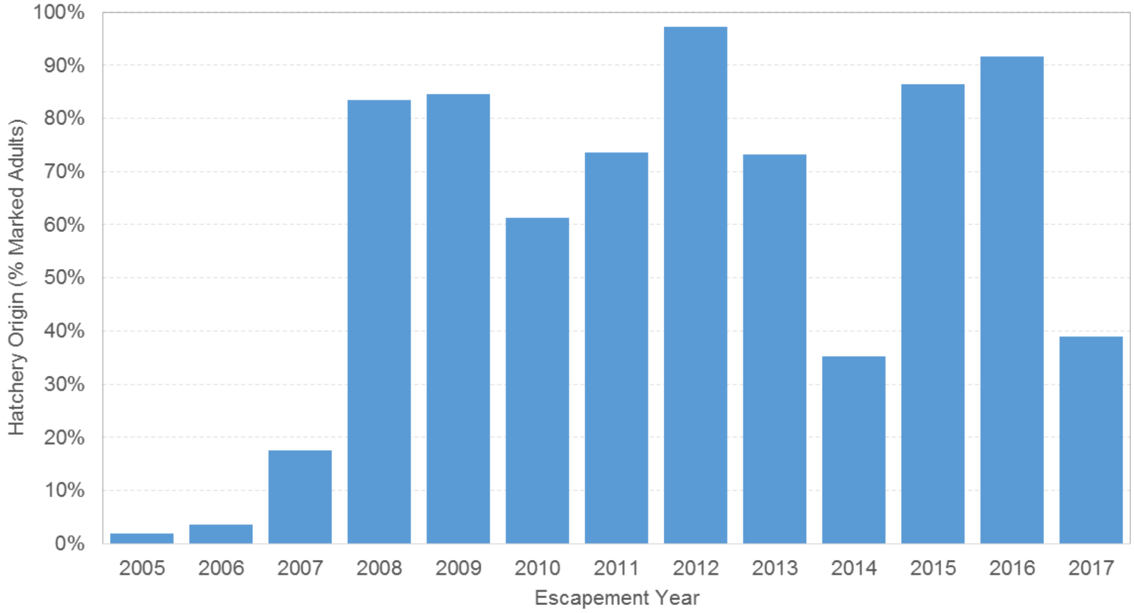

Figure 2. Proportion of hatchery-origin (marked) Sockeye Salmon to Cultus Lake (i.e., counted through Sweltzer Creek counting fence), 2005-2017.

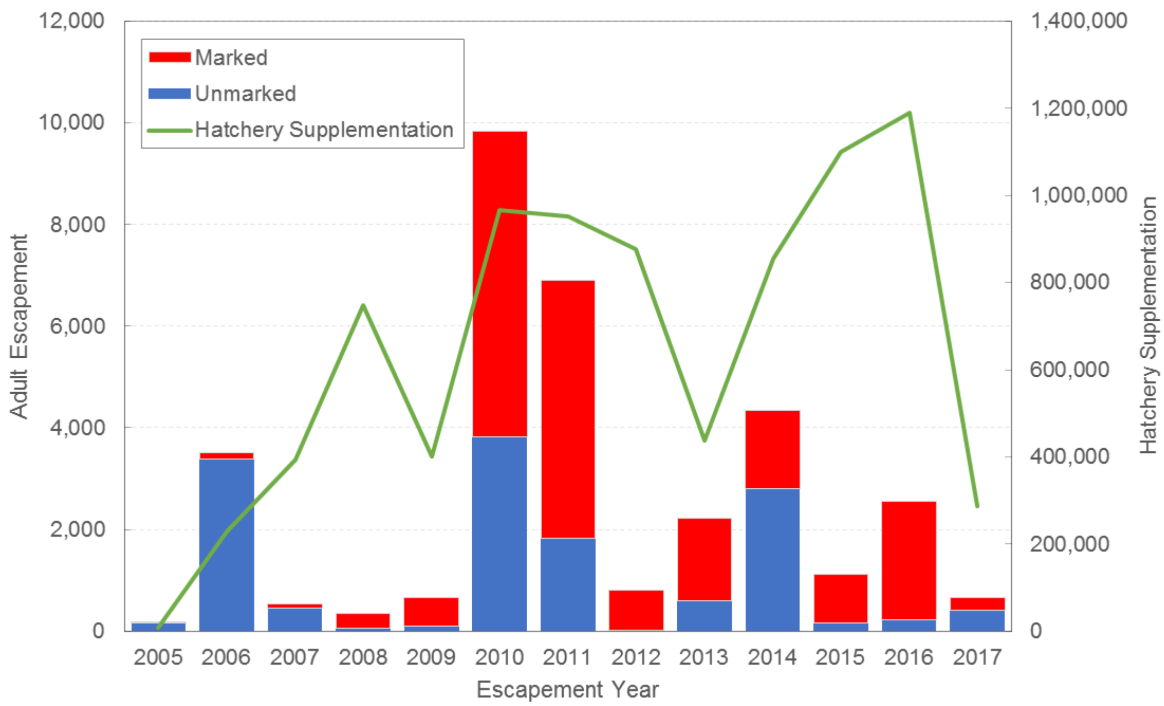

Figure 3. Total Cultus Lake Sockeye Salmon adult escapement (including broodstock) by mark status and total hatchery supplementation (fry/parr and smolt releases), 2005-2017. Note: hatchery supplementation is aligned with corresponding adult escapement year (e.g., the 2014 escapement year aligns with fry/parr released in Cultus Lake in 2011 and smolts released in Sweltzer Creek in 2012).

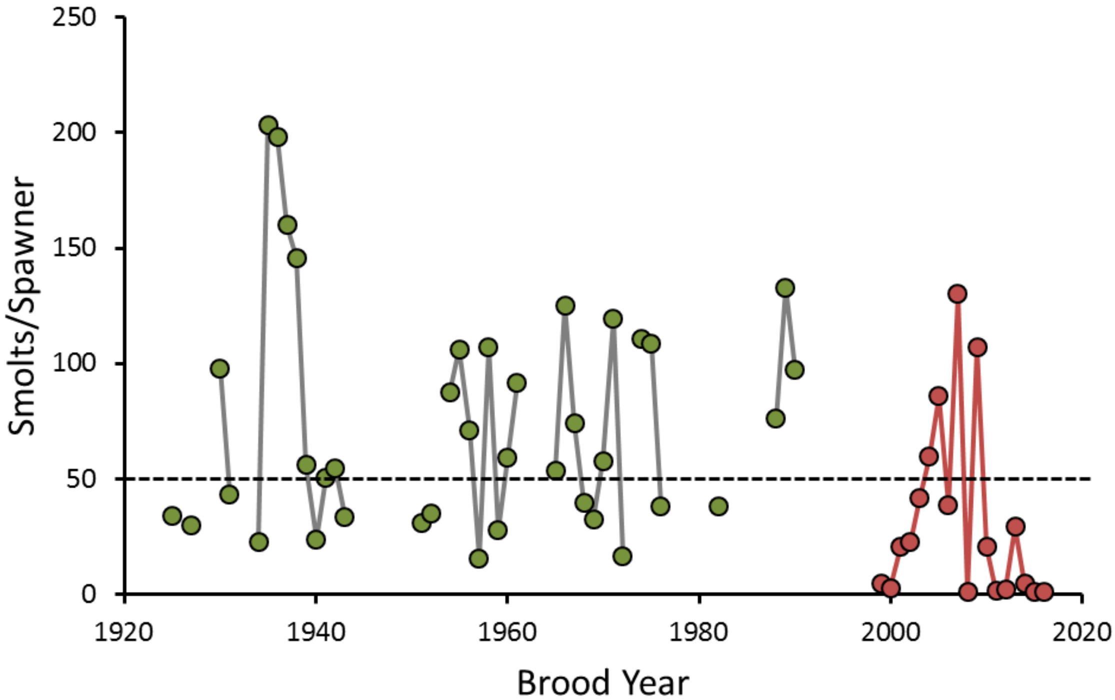

Figure 4. Smolt production rate for Cultus Lake Sockeye Salmon based on the ratio of unmarked smolts produced per adult spawner entering the lake for the historical (green) and recent (red) periods. Smolts per spawner includes both pre-spawning mortality and the mortality of eggs and juveniles in the lake. Dashed line at 50 smolts/spawners represents the level of production required to generate a self-sustaining population with a smolt survival rate of 2%.

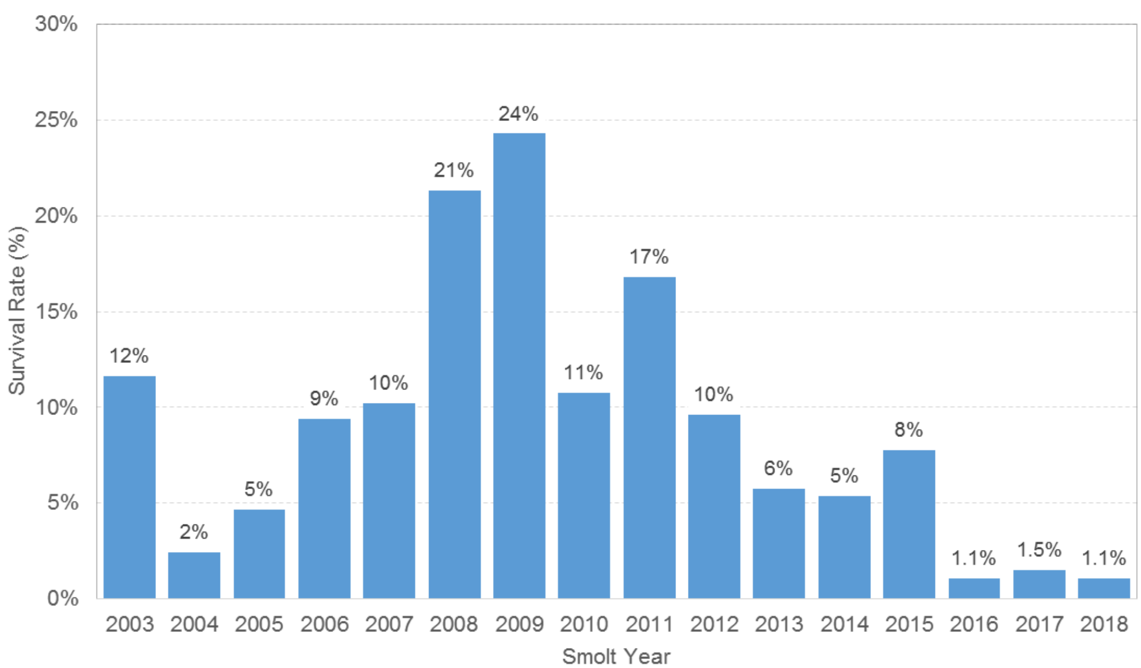

Figure 5. Cultus Lake Sockeye Salmon marked fry to smolt survival, 2003-2018. Note that fry releases in 2004 and 2005 were made at the shoreline of the lake, exposing the fish to predation at release. Fry releases in subsequent years were made mid-lake to mitigate this hazard.

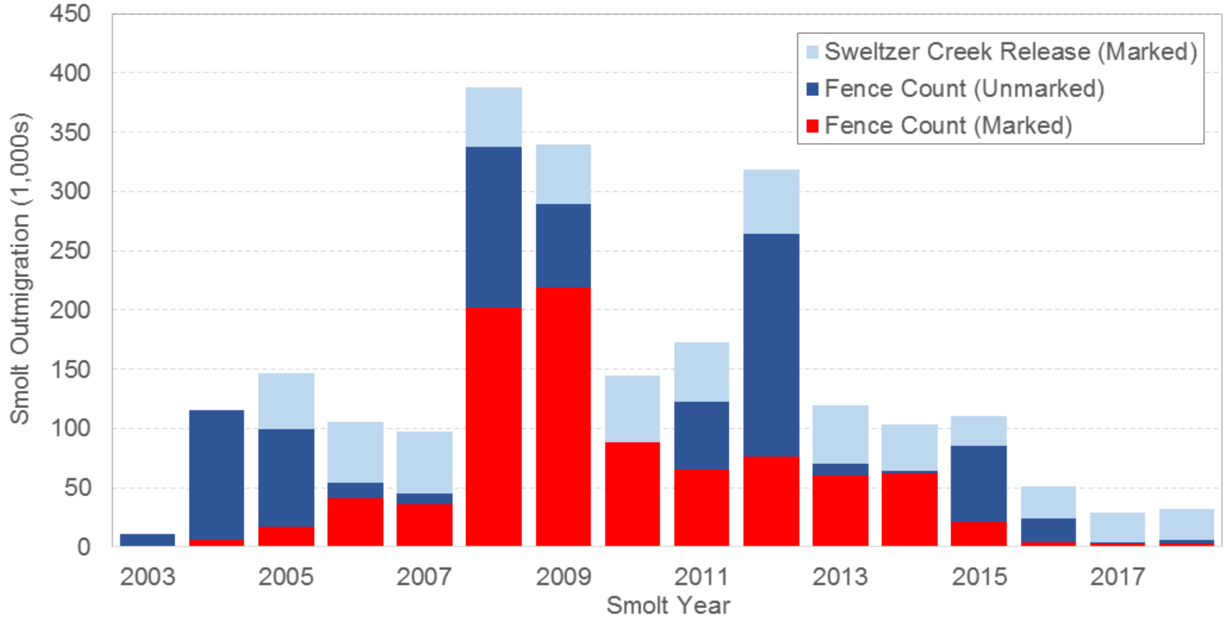

Figure 6. Total Cultus Lake Sockeye Salmon smolt outmigration (marked and unmarked), 2003-2018.

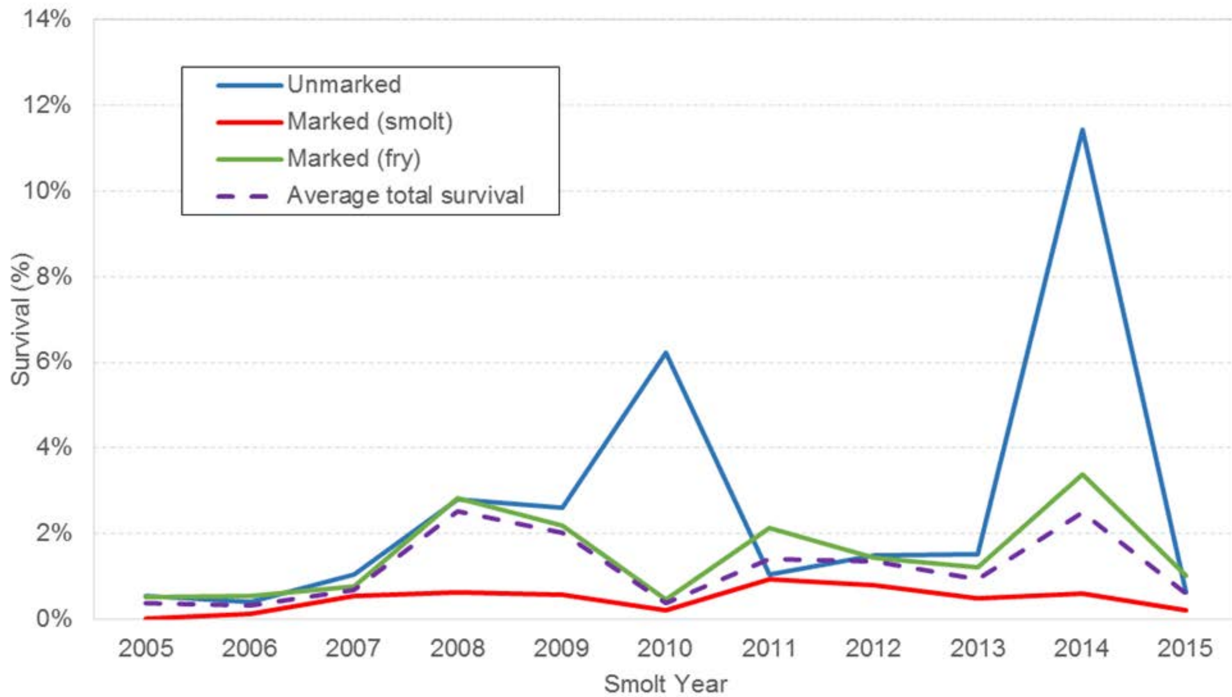

Figure 7. Cultus Lake Sockeye Salmon smolt-to-adult escapement survival rates for marked releases (fry and smolt) and unmarked juveniles for smolt outmigration years 2005-2015.

Note that estimates of survival for unmarked smolts for 2010 and 2014 are based on small sample sizes and are more uncertain than similar estimates for other years.

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Sources of information

This Science Response Report results from the Science Response Process of July 18, 2018 on the review of Science Information to Inform Consideration of Risks to Cultus Lake Sockeye Salmon in 2018.

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