WEST COAST VANCOUVER ISLAND BARKLEY SOCKEYE SALMON (*ONCORHYNCHUS NERKA*) STOCK ASSESSMENT IN 2024

CONTEXT

The Fisheries Management Branch of Fisheries and Oceans Canada (DFO) has requested that the West Coast Vancouver Island Barkley Sockeye Salmon (*Oncorhynchus nerka*) stock be assessed relative to reference points that are consistent with the DFO Precautionary Approach and provide harvest advice. This Fisheries Science Response is from the regional peer review meeting of May 26-27, 2025, on the West Coast Vancouver Island Barkley Sockeye Salmon (*Oncorhynchus nerka*) Stock Assessment in 2024.

SCIENCE ADVICE

Status

- The West Coast Vancouver Island Barkley Sockeye Salmon Stock Management Unit (Barkley Sockeye SMU) is above the Limit Reference Point (LRP) in 2024 with two component Conservation Units (CUs) originating from the Somass River watershed in the green status zone and the third CU originating from the Hucuktlis River watershed in the amber status zone.
- The Barkley Sockeye SMU should be considered in the Cautious Zone, as defined in the Sustainable Fisheries Framework, for management purposes due to the comigration of Sockeye from all component CUs, which causes *amber* status Hucuktlis Sockeye to be vulnerable to fisheries targeting Somass Sockeye.

Trends

- Hucuktlis spawner abundances have exhibited a declining trend since 2020.
- There are no apparent declining trends in productivity for any CU.
- Fish sizes, ages, and sex ratios appear relatively stable since 1980.
- Since the current Somass management plan was instituted in 1994, fishing mortalities of Somass Sockeye exceeded annual targets in 7 of 31 years (23%) by an average of 11%.
- Since the current Hucuktlis management plan was instituted in 2012 in accordance with the Maa-nulth Treaty, fishing mortalities of Hucuktlis Sockeye exceeded annual targets in 8 of 13 years (62%) by an average of 25%.

Ecosystem and Climate Change Considerations

- Prey availability and competition for food are the key drivers of fry-to-smolt survival and are predominately affected by organic nutrient levels in nursery lakes.

- Prey availability and predator and competitor impacts are key drivers of smolt-to-adult survival and are predominately affected by extremes in basin-scale ocean and climate factors that lead to fluctuations in marine food web productivity and species geographic distributions.
- High river water temperatures and hypoxic waters in upper Alberni Inlet impede adult Sockeye passage and exert physiological stress that leads to increased risk of disease outbreaks, pre-spawn mortality, and reduced reproductive success.
- Climate change is expected to negatively affect all ecosystem dynamics listed above. Milder, wetter winters are projected, with more extreme rainfall events leading to spawning ground scouring. Conversely, warmer, drier summers are projected, with more frequent and severe periods of high river water temperatures and low discharge. More frequent and severe El Niño’s are also projected, which will result in a depleted prey base and reduced foraging area for Sockeye rearing in the North Pacific.

Stock Advice

Harvest

- Further refine timing and locations of Alberni Inlet fisheries to reduce harvest rates on Hucuktlis Sockeye.
- Work with the Area 23 Harvest Committee to develop management adjustments that are triggered by environmental factors that affect upstream migration conditions in the Hucuktlis and Somass rivers.
- Prioritize early-season escapement to ensure that sufficient numbers of Sockeye spawners enter the rivers in cool conditions that minimize pre-spawn mortalities.

Habitat

- Continue habitat restoration in Clemens Creek and along the Hucuktlis Lake foreshore.
- Continue to inform strategic water use and planning in the Sproat and Stamp rivers through engagement with the Somass Fish Flows Committee.
- Consider engineering and infrastructure solutions to address climate change impacts of warming rivers and poor dissolved oxygen conditions in upper Alberni Inlet.

Enhancement

- Consider reinstating a fertilization program on Hucuktlis Lake through a cost–benefit perspective.

BASIS FOR ASSESSMENT

Assessment Details

Year Assessment Approach was Approved

Hyatt et al. (2003)

Assessment Type

Full Assessment.

Most Recent Assessment Date

1. Last Full Assessment: Fisheries and Oceans Canada (2012); Brown et al. (in prep.)[1]
2. Last Interim-Year Update: Brown (2024)

Stock Assessment Approach

1. Broad category: Multiple approaches used.
2. Specific category: Index-based (including fishery-dependent and fishery-independent indices); Stock-Recruitment Relationship, Other: Wild Salmon Policy Rapid Assessment, Risk Assessment.

Two approaches are generally used for salmon assessments: either index-based estimates of spawner abundance or stock-recruit relationships. Annually, allowable catch, fishing mortality, and fishing effort are determined through surplus to escapement (or spawner) requirements relative to expected abundance (generated through forecasts) and reference points (e.g., either biologically based targets such as benchmarks or LRPs informed by stock-recruit statistics or operational control points). The degree of reliance on spawner-index-based versus stock-recruit approaches is a function of data quality and availability. More recently, risk assessments are being used to better understand limiting factors through a life cycle framework and to inform the broader management context (e.g., Irvine et al. 2024).

[1] Brown, N., Stiff, H., Bendriem, N., Luedke, W., Gibeau, P., Bocking, R., Lane, J., McHugh, D., Cunningham, D., Murrell, G., LaFlamme, J., Dobson, D. In prep. Barkley Sound Lake-type Sockeye Salmon (*Oncorhynchus nerka*) Stock Assessment in 2024. Can. Sci. Advis. Sec. Res. Doc.

Stock Structure Assumption

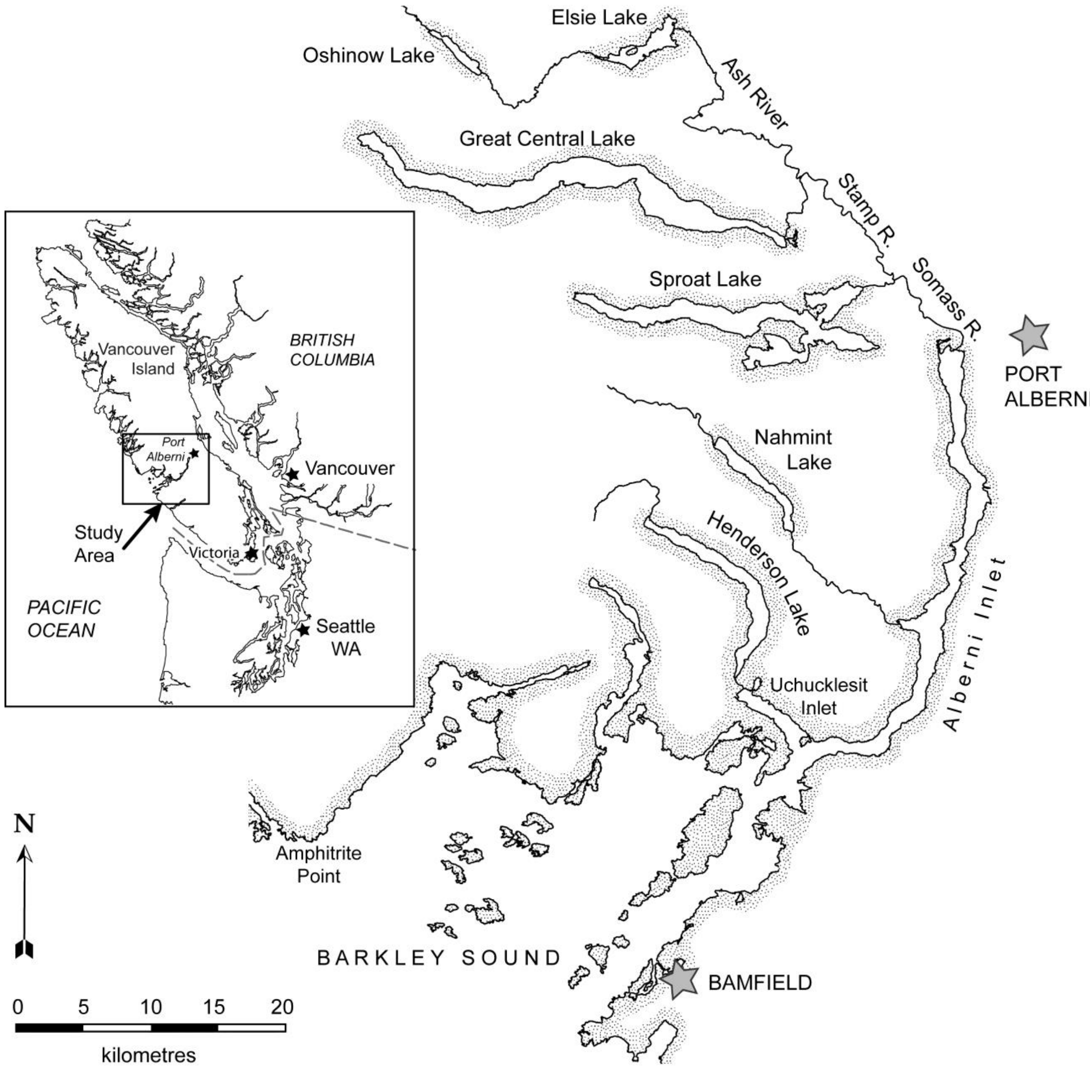

Figure 1. Map of Barkley Sound and Alberni Inlet showing major lakes and river systems. The three Conservation Units contained within the Barkley Sockeye Stock Management Unit are Great Central, Sproat, and Hucuktlis (formerly Henderson).

The Barkley Sockeye SMU includes three Conservation Units (CUs) of lake-type sockeye that are harvested in Alberni Inlet and Barkley Sound area fisheries: Great Central (SEL-13-08), Sproat (SEL-13-25), and Hucuktlis (formerly “Henderson,” SEL-13-09).

Two of the CUs (Great Central and Sproat Lake) spawn and rear within the greater Somass River watershed. Production and run-timing trends of these ‘Somass’ CUs are generally similar. As such, they are managed as an aggregate stock with a single harvest control rule (HCR) using common operational control points. Hucuktlis Lake sockeye are less productive and abundant than the two Somass CUs and are managed with a distinct HCR (see Harvest Decision Rule, below).

Populations of Sockeye within the target CUs are assumed to be genetically homogeneous. However, there are run timing variations within the populations and numerous discrete spawning locations, which may contribute to intra-population genetic diversity.

Table 1. Stock structure reference table for the Barkley Sound Stock Management Unit and other nearby stocks.

Stock Management Unit (SMU)	Conservation Unit (CU)	CU Index	Designatable Unit (DU)	DU number
Barkley Sound Sockeye	Great Central Lake	SEL-13-08	Great Central	72
Barkley Sound Sockeye	Sproat Lake	SEL-13-25	Sproat	86
Barkley Sound Sockeye	Hucuktlis Lake	SEL-13-09	Henderson	73
WCVI Sockeye - Other	Maggie Lake	SEL-13-15	Maggie	79
No designated SMU	WCVI River Type	SER-10	West Vancouver Is	30

Assessment Framework

Stock-recruit models inform biological reference points, operational control points, and the HCR. Annual pre-season run size forecasts guide implementation of the abundance-based HCR (Figure 2). In-season run size adjustments are made using observed stock abundance, average run timing curves, and other information such as the stock and age composition, environmental conditions, and test fishery observations. Run sizes of the three component CUs, including age and stock composition, are reconstructed annually to estimate and evaluate trends in stock status, catch, exploitation rate, recruitment, and demographic parameters.

Annual smolt abundance estimates are used to develop pre-season run size forecasts, generate marine survival rate indices, and to monitor freshwater productivity.

Reference Points

Biological reference points used for assessment and management of Barkley Sockeye stocks were reviewed and updated in this assessment (Brown et al. in prep.[1]; Table 2). These updated references were used to evaluate statuses of the component CUs following the Wild Salmon Policy rapid status approach (Pestal et al. 2023; DFO 2024).

Table 2. Reference points for the Barkley Sockeye Stock Management Unit and its component Conservation Units. Numeric ranges in brackets indicate the 80% credible intervals of values.

Assessment Unit	Reference Point	Previous Value (based on earlier assessment)	Previous value description / parameter	Updated Value (based on this assessment)	Updated value description / parameter
Barkley Sockeye SMU	CU-status-based LRP	NA	NA	Cautious Zone	1 CU is *Amber* and is vulnerable to fisheries targeting *Green* CUs

Assessment Unit	Reference Point	Previous Value (based on earlier assessment)	Previous value description / parameter	Updated Value (based on this assessment)	Updated value description / parameter
Great Central Lake CU	Lower Biological Benchmark	[1]29290	S_{gen}	33680 (20667–52929)	S_{gen}
Great Central Lake CU	Upper Biological Benchmark	[1]91640	80% S_{MSY}	94790 (76306–121636)	80% S_{MSY}
Great Central Lake CU	Removal Reference	NA	NA	58% (45–68%)	U_{MSY}
Sproat Lake CU	Lower Biological Benchmark	[1]12060	S_{gen}	17321 (9426–31329)	S_{gen}
Sproat Lake CU	Upper Biological Benchmark	[1]65570	80% S_{MSY}	71509 (58415–90947)	80% S_{MSY}
Sproat Lake CU	Removal Reference	NA	NA	67% (54–77%)	U_{MSY}
Hucuktlis Lake CU	Lower Biological Benchmark	[2]3000	Unknown	9576	25th percentile of escapement from 2007–2024
Hucuktlis Lake CU	Upper Biological Benchmark	[2]10000	Unknown	13948	50th percentile of escapement from 2007–2024
Hucuktlis Lake CU	Removal Reference	NA	NA	48% (17–74%)	U_{MSY}

[1] These values were determined *circa* 2010 via spawner–recruit analyses that were not formally published.
[2] These values were proposed *circa* 2014 from a weight of evidence approach considering the available spawner–recruit relationship and Hucuktlis lake fry carrying-capacity estimates and were not formally published.

Other Reference Points

Temporal trends in productivity and in population demographic traits were considered as additional indicators of stock status in this assessment (see details in Brown et al. in prep.[1]).

Management Objectives

The Barkley Sound Sockeye Management Plan[2] sets out the following detailed objectives, which were developed through an ongoing consensus-based adaptive management process involving First Nations and stakeholders (i.e., the ‘Area 23 Harvest Committee’):

- Somass sockeye: The Fishery Reference Point-Lower (FRP-L) of 200,000 (Table 3) and variable harvest rate strategy take into account the objective of returning to commercially fishable abundance of 700,000 within one generation while achieving an average annual run of 700,000.

[2] Dobson, D, and the Area 23 Harvest Committee. In prep. Area 23 (Alberni Inlet, Barkley Sound) Sockeye Fishery Local Fishery Management Plan.

- Hucuktlis sockeye: The objective of the Hucuktlis Sockeye harvest strategy is to permit access to Maa-nulth First Nations for fisheries while limiting incidental catch in other Area 23 Sockeye fisheries to allow rebuilding (Table 3).

Table 3. Management reference points for Barkley Sockeye. The 'Somass Sockeye' management unit reflects the co-management of the Great Central and Sproat CUs; the 'Hucuktlis Sockeye' CU is managed separately.

Management Unit	Reference Point	Value	Description
Somass Sockeye	Fishery Reference Point–Lower	200,000 return	Minimal abundance with some allowable harvest (restricted, First Nation Treaty and Food Social and Ceremonial fisheries prioritized)
Somass Sockeye	Fishery Reference Point–Upper	350,000 return	Minimal abundance with all sector fishing opportunities (i.e., including commercial seine)
Somass Sockeye	Target Reference Point	350,000 escapement, 700,000 return	Long term production goal: the HCR is designed to achieve an aggregate return of 700K with 350K escapement to meet production objectives
Hucuktlis Sockeye	Fishery Reference Point	15,000 return	Level at which allowable harvest rate incrementally increases from 15%. Allowable harvest is restricted to 15% incidental catch below this threshold.
Hucuktlis Sockeye	Target Reference Point	25,000 return	Rebuilding goal to meet production objectives (i.e., delimits 'low run size' from 'moderate run size' range)

Harvest Decision Rule

Somass (Great Central and Sproat Lake) Sockeye:

For the aggregate Somass stock, the allowable harvest rate increases with abundance from 10% at run sizes above 200,000 to a maximum of 67% at 1.8 million (Figure 2). The spawning escapement target is 350,000 adults (Table 3). However, to meet socio-economic and stock evaluation objectives, escapement targets increase gradually with run size (i.e., at run sizes >200,000 and <700,000 the escapement target is less than 350,000, while at run sizes >700,000 the escapement target incrementally increases above 350,000). Additional decision rules ensure CU-specific escapement goals are met for years when either the production or run timing of the two stocks diverge. Also, the management of the fisheries targeting the Somass stock is structured to avoid harvest of less abundant Hucuktlis Lake Sockeye through time and area closures.

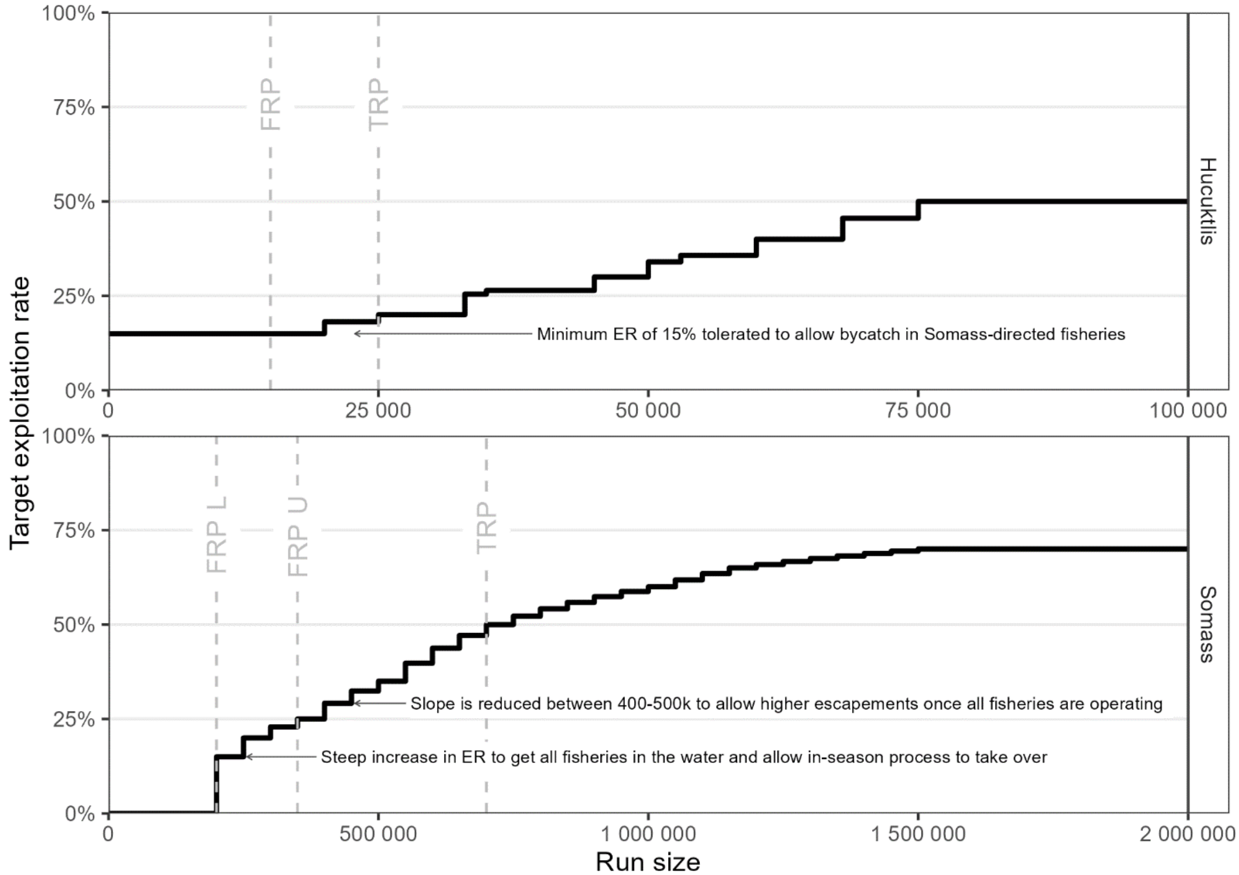

Figure 2. Barkley Sockeye variable harvest strategy plotted as a function of Somass and Hucuktlis Sockeye run sizes. Labeled vertical lines show management reference points.

Hucuktlis Sockeye

For the Hucuktlis CU, the allowable harvest rate is limited to 15% or less at run sizes less than 15,000 (Figure 2). At run sizes greater than 15,000, the allowable harvest rate increases with abundance to a maximum of 50% at run sizes at or above 75,000 (Figure 2).

Stock and Habitat Enhancement

Lake Fertilization

- Great Central Lake was fertilized from 1970–1973 and then annually from 1977–present.
- Hucuktlis Lake was fertilized from 1979–1999 and once again in 2007; after which the program was discontinued.
- Sproat Lake was fertilized as a trial from 1985–1986 but the program was subsequently discontinued due to algae blooms.

Hatchery Enhancement

- Hucuktlis Lake Hatchery released fed Sockeye fry annually from 1992–2007. Total hatchery production during that period ranged from about 70,000–2,300,000 eggs (released fry numbers were not estimated) depending on the year. The program was discontinued after 2007.

Habitat Enhancement

- Fishways were constructed in 1927 (with a major upgrade in 1954) at Stamp Falls (on the Stamp River, the outlet of Great Central Lake) and in 1951 on the Sproat River (the outlet of Sproat Lake) to increase habitat accessibility for Great Central and Sproat Sockeye (Figure 5).
- Spawning channels were constructed in Clemens Creek in the early 1990s to expand available habitat capacity for Sockeye.

Data

Adult Barkley Sockeye abundances are estimated from fishway counts (Great Central and Sproat), spawning ground surveys and fence counts (Hucuktlis), and fishery catch reporting and monitoring programs. Fishway counts for the Great Central and Sproat populations are assumed to estimate true abundance to within 5%. Spawning ground surveys and fence counts for the Hucuktlis population are moderately accurate and assumed to estimate true abundance to within 10–20%. Area 23 fishery catch estimates are assumed accurate to within 5–10%. Genetic samples collected routinely from Area 23 fishery catches are used to apportion catches among the three local Sockeye CUs. Barkley Sockeye fry abundances are estimated by annual Acoustic and Trawl Surveys (ATS) in Great Central, Sproat, and Hucuktlis lakes. Scale samples for aging are collected from emigrating smolts in annual downstream trapping surveys in Robertson Creek and the Sproat and Hucuktlis rivers. See Brown et al. (in prep.)[1] for details on Barkley Sockeye assessment methodologies.

ASSESSMENT

The plots below show time series of catch, escapement, exploitation rates, and recruitment for the Barkley Sockeye aggregate (Figure 3) and for each of the component CUs (Figure 4, Figure 5, Figure 6) spanning roughly the last half century.

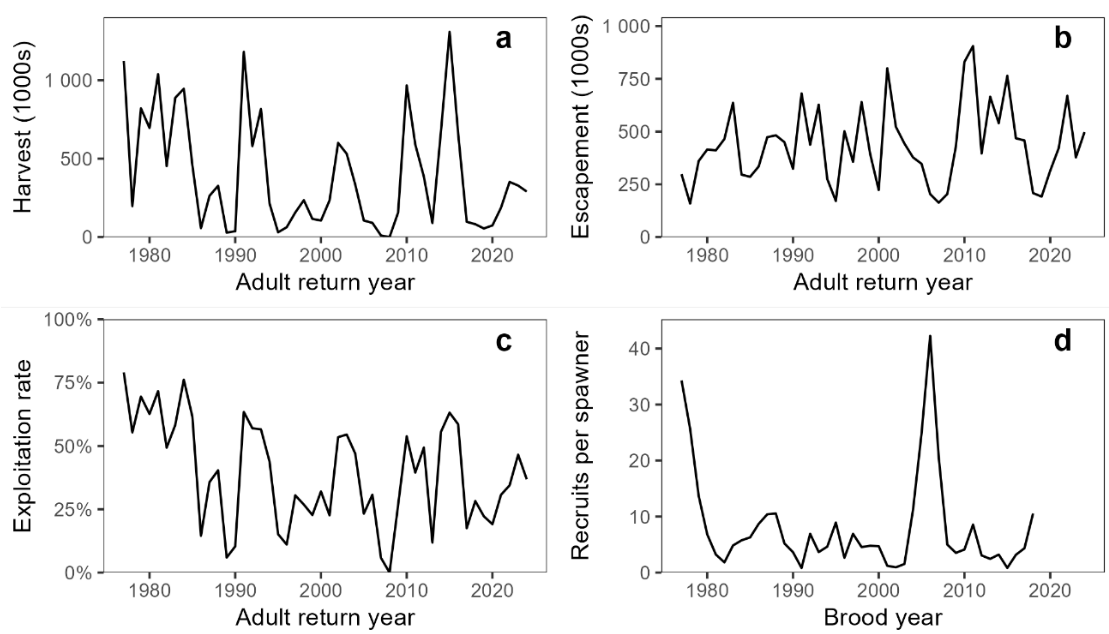

Figure 3. Barkley Sockeye Stock Management Unit time series of harvest (a), escapement (b), exploitation rate (c), and recruits per spawner (d).

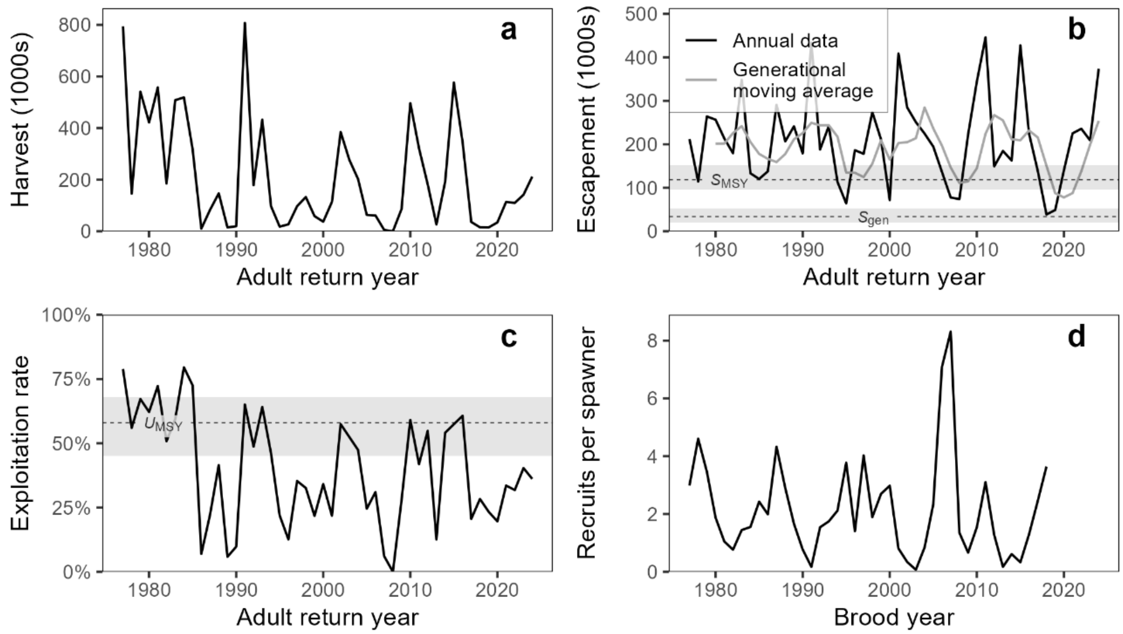

Figure 4. Great Central Sockeye Conservation Unit time series of harvest (a), escapement (b), exploitation rate (c), and recruits per spawner (d). Labeled reference lines and shaded areas show reference point medians and 80% credible intervals, respectively.

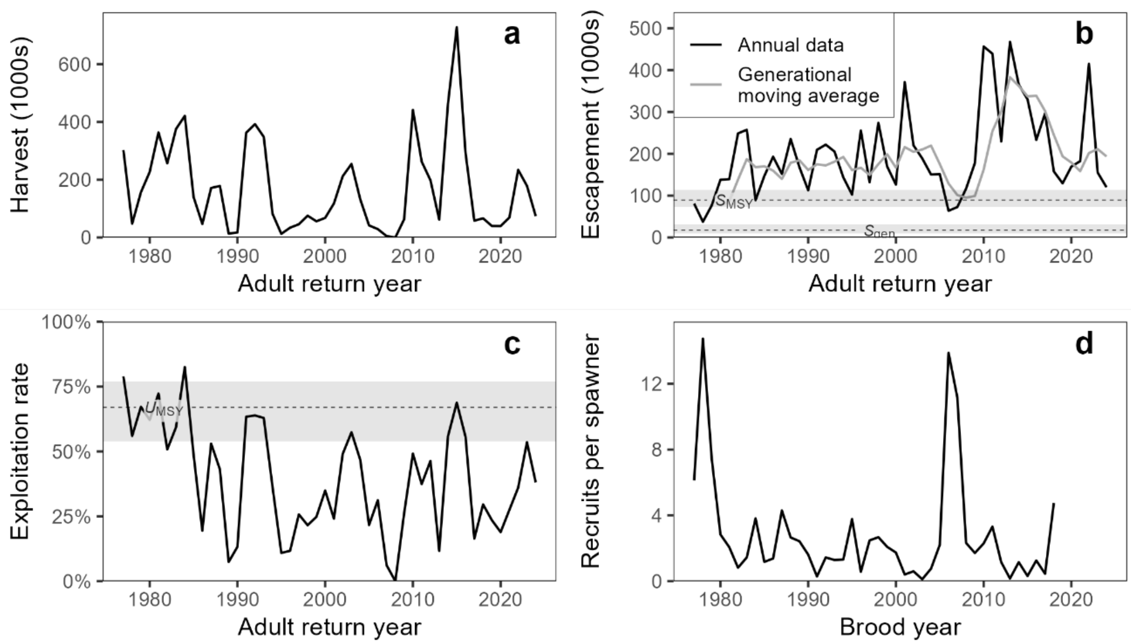

Figure 5. Sproat Sockeye Conservation Unit time series of harvest (a), escapement (b), exploitation rate (c), and recruits per spawner (d). Labeled reference lines and shaded areas show reference point medians and 80% credible intervals, respectively.

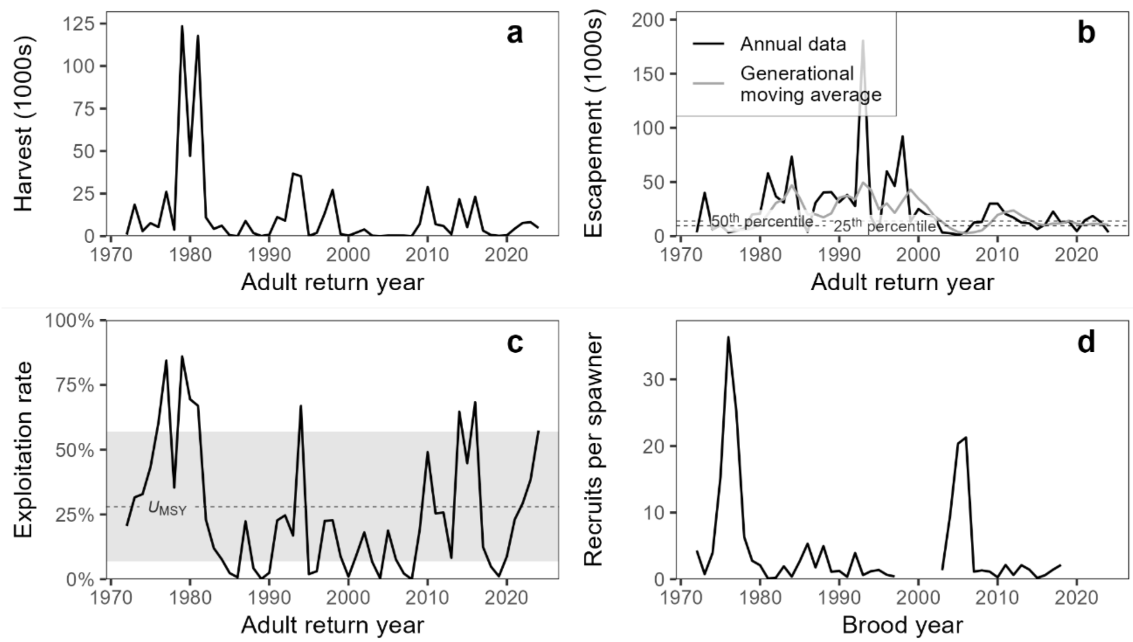

Figure 6. Hucuktlis Sockeye Conservation Unit time series of harvest (a), escapement (b), exploitation rate (c), and recruits per spawner (d). Labeled reference lines and shaded areas show reference point medians and 80% credible intervals, respectively.

Stock Status and Trends

Table 4 summarizes status determinations for the Barkley Sockeye SMU and its 3 component CUs. Overall the Barkley Sockeye SMU is in the "Cautious Zone" (Fisheries and Oceans Canada 2009).

Table 4. Stock reference points and statuses for Barkley Sockeye CUs and for the SMU aggregate

Unit	Recent generation geometric mean spawner abundance	Lower reference	Upper reference	WSP status	PA stock status
Great Central CU	202515	33680	94790	Green	NA
Sproat CU	138775	17321	71509	Green	NA
Hucuktlis CU	10584	9576	13948	Amber	NA
Barkley Sockeye SMU	NA	All CUs above LBBs	NA	NA	Cautious Zone

Spawner abundance

Total escapement counts have exceeded lower biological benchmarks (S_{gen}) in nearly every year since the spawner–recruit time series for the Great Central and Sproat CUs began in 1977 (Figure 4b; Figure 5b). Great Central escapement numbers have exceeded its upper biological benchmark in 34 of the last 48 years (71%; Figure 4b) and Sproat escapement numbers have exceeded its upper biological benchmark in 41 of the last 48 years (85%; Figure 5b). Hucuktlis escapement numbers have exceeded its lower biological benchmark in 39 of the last 53 years (73%; Figure 6b) and have exceeded its upper biological benchmark in 29 of the last 53 years

(55%, Figure 6b). However, note that Hucuktlis escapement numbers have fallen below its lower biological benchmark in 2 of the last 5 years (in 2020 and 2024; Figure 6b).

Fishing Mortality

Recorded (and presumed) harvest of Barkley Sockeye occurs entirely within terminal fisheries of Barkley Sound and Alberni Inlet. Total annual catches of Barkley Sockeye have ranged between 0–1 300 000 and have averaged 234 000 over the last half-century while aggregate exploitation rates have varied between 0–77%.

Recruitment

Adult recruitment does not exhibit an overall increasing or decreasing trend across the time series for any of the three Barkley Sockeye CUs (Figure 4d, Figure 5d, Figure 6d). It is noteworthy that both the lowest and highest recruits-per-spawner events for the SMU aggregate have occurred post-2000 (Figure 3d), likely signaling a transition into a regime of higher volatility in population productivity.

History of Harvest Management

Area 23 Sockeye fisheries have predominately operated at sustainable levels throughout the last half-century. The Kobe plots in Figure 7 show that, for the majority of years in each CU's time series, spawner abundances and harvest levels have been in the "sustainable zone" (i.e., bottom-right quadrant). For the Somass CUs in particular—Great Central and Sproat—only 3 years fall within the "overfishing zone" (top-left quadrant), all of which occurred in the 1970s–1980s. These data indicate harvest management has been largely successful for Somass Sockeye.

In-season assessments for Hucuktlis Sockeye are more limited than for Somass Sockeye. The resulting lack of assessment information has increased fishery management implementation error leading to more frequent transgressions of target harvest rates (Figure 8). Fishing thus remains an important limiting factor for Hucuktlis Sockeye.

Uncertainty around when and where Hucuktlis Sockeye comingle with Somass Sockeye within Alberni Inlet is the key challenge to mitigating Hucuktlis harvest. Total allowable catch is high when Somass Sockeye are abundant, which means that even small proportions of Hucuktlis Sockeye in the catch composition can translate to large harvest rates. This effect is compounded when Hucuktlis Sockeye migrate further North into Alberni Inlet than expected and enter areas of Somass-directed fisheries. This northward prevalence of Hucuktlis Sockeye beyond the mouth of Uchucklesit Inlet is perhaps attributable to poor in-river migration conditions and a tendency for Somass and Hucuktlis Sockeye to converge in areas of Alberni Inlet with favourable holding conditions.

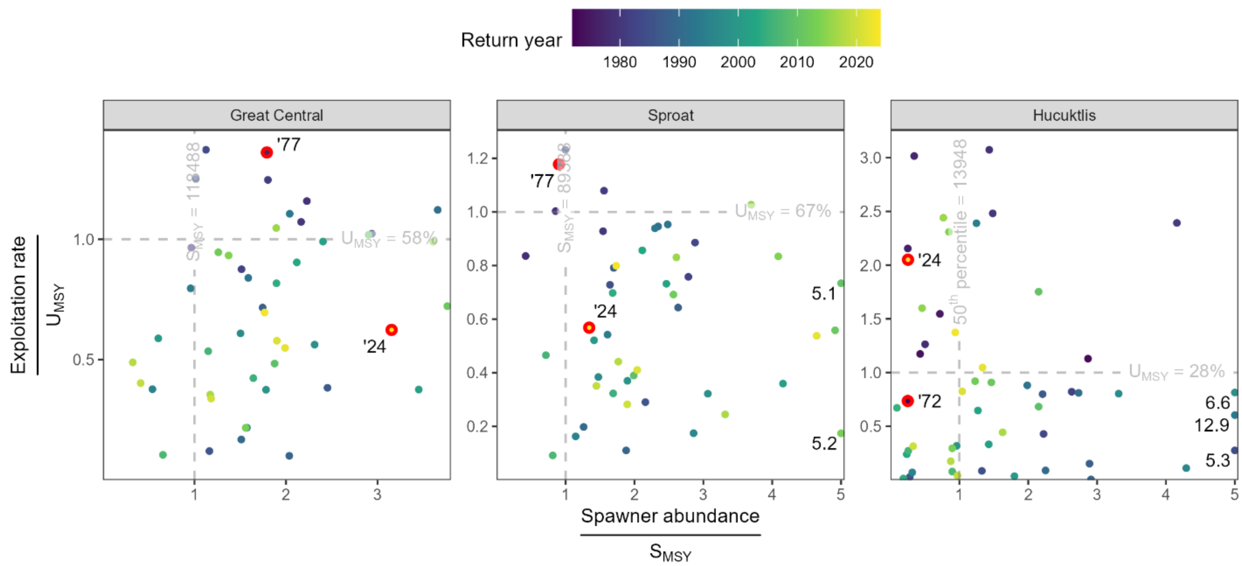

Figure 7. Kobe plots for Barkley Sockeye Conservation Units (CUs). Red circled and labeled points indicate the beginning and end years of each CU's data time series. Horizontal axis limits are constrained to aid interpretability; labeled points flush with the righthand limits of each panel indicate points that exceeded the fixed axis limit, with labels stating their true x-values.

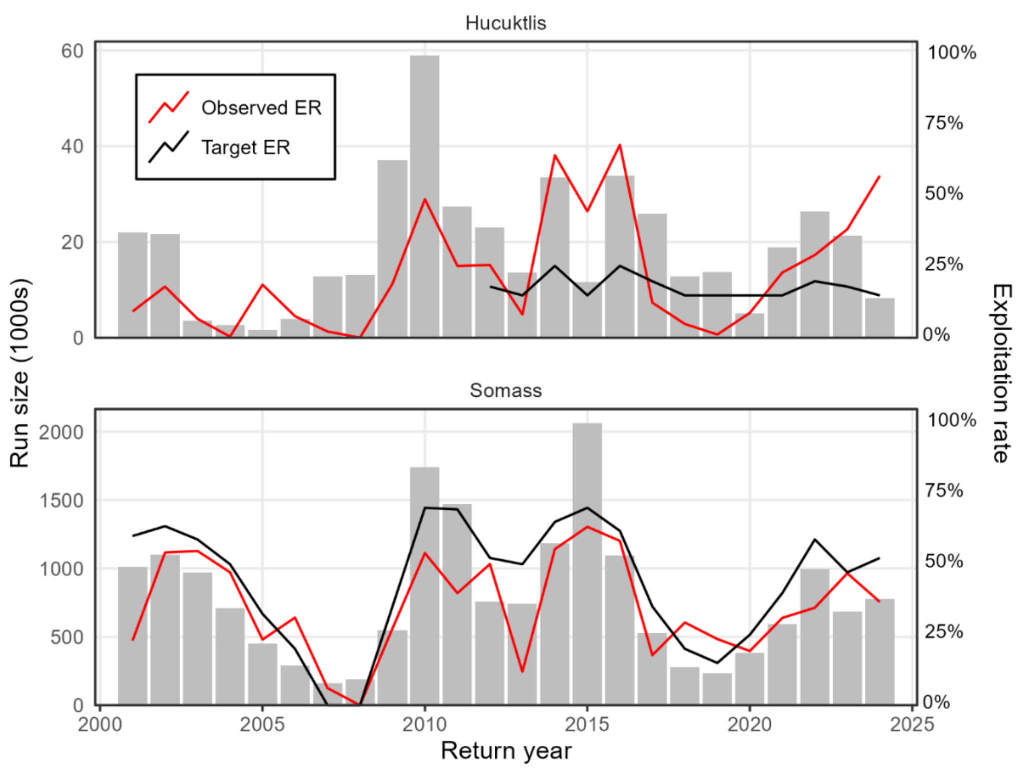

Figure 8. Time series of Hucuktlis versus Somass Sockeye abundance and exploitation rates (ERs) from 2000–present. Grey bars indicate total run size (summed Great Central and Sproat abundances in the Somass panel) and are plotted with respect to the left axis. Red and black lines show observed and target ERs, respectively, and are plotted with respect to the right axis. Target ERs are a function of total run size for each stock (see Figure 2).

Ecosystem and Climate Change Considerations

Freshwater Impacts

Global climate models project consistent warming across all seasons along the WCVI. Projected air temperature changes translate into mean water temperatures that exceed Sockeye thermal tolerance levels (20 °C) for >80% of days during peak migration (July) by the 2050s in the Somass River. Stream temperatures exceeding 20 °C inhibit adult migration and subsequent spawning success.

An annual precipitation increase of 10% is projected by the 2080s, falling disproportionally in the late fall through spring seasons, with summer receiving 10% less rain (Stiff et al. 2018). More intense autumn and winter storms will exacerbate flood and scour events in tributary spawning grounds and reduce egg-to-fry survival. Intensifying summer droughts will reduce water quality and supply for adult Sockeye migration. Low gradient, shallow sections of streams and lake beaches are prone to dewatering during drought, potentially desiccating redds or stranding Sockeye fry.

Marine Impacts

Regional ocean models (e.g., Holdsworth et al. 2021) project decreasing dissolved oxygen levels in upwelled waters along the west coast of North America. This trend, linked to climate change, results from warmer, less dense surface waters amplifying stratification and limiting oxygen exchange in the water column. Currently, summer dissolved oxygen concentrations in upper Alberni Inlet appear to be forced by estuarine circulation and wind-driven upwelling processes drawing from deep marine waters during spring ‘inlet renewal’ events. During warm-phase El Niño–Southern Oscillation (ENSO) years, stronger winds upwell deeper, low-oxygen waters into the inlet, exacerbating oxygen depletion caused by the decaying industrial fiber mat (Birtwell et al. 2014). Conversely, dissolved oxygen concentrations in the upper inlet during cool phase ENSO years resemble more favourable pre-effluent levels (>4 $mg{\cdot}L^{-1}$).

Stock Advice

Factors affecting survival and productivity

Table 5. List of key factors affecting Barkley Sockeye survival and population productivity across major life cycle stages.

Life Stage	Key factors affecting survival and productivity (interactions with climate change possible at all life stages)
Adult upstream migration	High river water temperatures >20°C that are physiologically taxing and lead to reduced swimming speeds, reduced fecundity, and exacerbate vulnerability to pathogens, parasites, and, ultimately, pre-spawn mortality
Adult spawning	Disease outbreaks
Egg incubation and fry emergence	High creek flows or flooding events leading to scouring of redds in tributary creeks, particularly Clemens Natural or anthropogenic[3] drawdown of lake water levels in the months following egg deposition, leading to dewatering of redds in waters <3 m depth

[3] Anthropogenic drawdown of Great Central Lake water levels due to dam management and operations at the lake outlet.

Life Stage	Key factors affecting survival and productivity (interactions with climate change possible at all life stages)
	Egg predation by piscivorous fish (e.g., unquantified impacts from invasive carp in Sproat Lake)
Freshwater rearing in lakes (2–3 years)	Availability of quality prey, particularly large cladocerans and copepods Predation by piscivorous fish, such as trout or juvenile Coho Competition for prey with other fishes, such as sticklebacks, juvenile trout, or other salmon fry
Downstream and coastal marine migration	Availability of quality prey, particularly krill (euphausiids) Predation by piscivorous fish, such as hake or mackerel, in coastal or continental shelf waters
Ocean rearing (1–3 years)	Basin-scale ocean and climate drivers such as El Niño lead to poor prey availability and possibly range reduction due to supra-optimal temperatures Competition with other salmon species, particularly Pink salmon, for prey Predation by marine mammals and piscivorous fish
Terminal marine migration	Fishery management implementation error leading to higher than intended exploitation rates on Hucuktlis Sockeye Warm river temperatures and surface marine waters in Alberni Inlet combined with periods of poor dissolved oxygen below the thermocline subject Sockeye to a “temp-oxy squeeze” that is physiologically taxing and can lead to mass mortalities Predation by pinnipeds near river mouths

Strategies to support rebuilding and maintain future production

Strategies to address limiting factors, support rebuilding, and maintain future production are summarized below. Further work with resource managers, First Nations, and stakeholders is required to identify, evaluate, and prioritize localized prescriptions within a cost-benefit and feasibility framework.

Harvest

Further refinement of management strategies (both pre- and in-season) that focus on timing and location of commercial and recreational fisheries is required to reduce harvest rates on Hucuktlis Sockeye, particularly during years of delayed Sockeye migration. The Area 23 Harvest Committee has proven highly effective in balancing harvest and conservation goals and now the development of improved management strategies through the roundtable process is necessary to address periodic over-harvest of Hucuktlis Sockeye.

Climate change will continue to pose challenges for Area 23 fishery management by increasing the frequency and duration of thermal barriers to upstream migration, with associated issues of longer holding periods in marine waters, vulnerability to a ‘temp-oxy squeeze,’ and increased pre-spawn mortality. Fishery management must adapt to meet these mounting pressures. Prioritizing early-season escapement will increase the likelihood that sufficient numbers of Sockeye spawners can enter the rivers in cool conditions that minimize pre-spawn mortalities.

Freshwater habitat

Freshwater survival of Hucuktlis Sockeye can be facilitated by improving spawning ground conditions through riparian restoration, stream stabilization, riparian buffer and stream shading, spawning channel development, and removal of historic logging debris. Debris and detritus from historic logging cover extensive sections of Hucuktlis Lake beach spawning habitat that were historically utilized by Sockeye. Removal of this debris and restoration of gravel substrate could expand spawning habitat capacity.

In the Somass system, effective management of river flows and lake levels utilizing existing dam and weir infrastructure can improve conditions for both Sockeye adults and the eggs they deposit. The Somass Fish Flow Committee (chaired by West Coast Aquatic) advises Domtar Paper on management of the Stamp and Sproat flow control infrastructure for fish needs. The committee includes representatives from DFO, the Province of BC, municipal and First Nation governments, and other local stakeholders and experts. The committee is working to formalize decision points for year-round flow and lake level management to benefit salmonids. Ongoing and recommended activities of the Committee include:

- Establish environmental flow needs for the Stamp, Sproat, and Somass rivers related to salmon migration and other stakeholder interests.
- Formalize decisions for storing and releasing water according to environmental flow needs.
- Develop and implement an integrated Decision Support System to manage water storage and flow timing using real-time data inputs.
- Upgrade flow control structures at Great Central Lake Dam and Sproat Weir. Automated control of stop-logs and weir plates or installation of mechanized doors will improve the ability to fine-tune river discharges. Constructing a high-water spillway at the Great Central Lake dam would afford greater water storage capacity through the winter.

An additional mitigation option with potential application in the Somass system is summer spillage of cold water from deep in Great Central and Sproat lakes to facilitate adult Sockeye migration. Water pump or siphon systems at Great Central Lake dam and Sproat Weir could be constructed to supply deep, cold lake water into downstream flows to mitigate low flow and high temperature impacts during upstream migration (Lill et al. 2012).

Marine habitat

Restore habitat for juvenile salmonids in the Somass estuary. Shoreline armouring and log booming reduce salmonid prey abundance, reduce areas of predation refuge, and change the spatial distribution of juvenile salmon. Replacing armoured shorelines with nature-based soft-shore alternatives can mitigate these impacts by restoring habitat-forming processes. Additionally, log-boom siting should be informed by ecosystem science to avoid sensitive habitats.

Frequent blooms of green algae have been reported in the lower Somass River and Somass Estuary. These blooms are from a filamentous green algae called *Cladophora* that is associated with high phosphorus arising from anthropogenic inputs. *Cladophora* blooms decrease water quality and inhibit growth of beneficial aquatic vegetation and should be mitigated by identifying and reducing sources of the nutrient loading.

Enhancement

No changes are recommended to the existing fertilization regimes in place for Great Central and Sproat lakes (i.e., annual fertilization in Great Central, no fertilization in Sproat). However, revisiting possible fertilization scenarios for Hucuktlis Lake may be appropriate. Hucuktlis Lake is classified as “ultra-oligotrophic” due to high flushing rates that constrain organic nutrient levels resulting in a low carrying capacity for Sockeye fry. Reinstating fertilization of Hucuktlis Lake should be considered within a cost–benefit and risk-mitigation framework. Fertilization has associated risks and challenges (e.g. costs, algae blooms, possibility of increased stickleback production) but may enhance Sockeye production, particularly if combined with improvements in spawning habitat that improve egg-to-fry survival.

No hatchery supplementation is recommended for any of the Barkley Sockeye CUs, with the possible exception of Hucuktlis. Small-scale, experimental hatchery production could be explored as a tool to yield further information on key limiting factors for the stock. For example, contrasting survival rates between hatchery and wild fish might clarify the relative magnitudes of freshwater versus marine mortality drivers.

BYCATCH

Within Barkley Sound and Alberni Inlet, there are component populations of WCVI river type Sockeye CU (SER-10; i.e., Carnation Creek, Effingham River, Nahmint River, Sarita River, and Toquaht River populations) that may be subject to some bycatch in fisheries. There is an additional lake-type Sockeye CU in Barkley Sound that is geographically and temporally separated from Area 23 Sockeye fisheries and likely not subject to significant bycatch (Maggie Lake, SEL-13-15).

There are both summer and winter wild steelhead runs in the Somass River. The hatchery-enhanced summer steelhead run is vulnerable to Barkley Sockeye fisheries. Fishing techniques, such as the use of barbless hooks or recovery boxes, can help reduce the mortality of released steelhead bycatch in Sockeye fisheries. If required, time and area closures as well as night fishing restrictions are used to reduce bycatch.

SOURCES OF UNCERTAINTY

- Uncertainty in Great Central and Sproat spawner numbers due to unquantified pre-spawn mortalities above the Sproat and Stamp fishways, where escapement counts are collected.
- Uncertainty in Hucuktlis total escapement numbers due to lack of survey coverage to enumerate spawners in Hucuktlis Lake and methodological uncertainty in escapement counts from the Hucuktlis River fence and Clemens Creek spawner counts.

Research Recommendations

- Develop a pre-season predictive model based on ocean conditions (e.g., sea surface temperatures during ocean entry), climate indices (e.g., ENSO, PDO) and related environmental factors (e.g., cumulative upwelling) to forecast Somass River thermal barrier event likelihood and upper Alberni Inlet summer sub-halocline dissolved oxygen concentrations.
- Develop methods to estimate pre-spawn mortality rates of Somass Sockeye based on enroute environmental factors and fish condition.
- Conduct surveys of Great Central Lake beach spawning grounds during egg incubation and hatch periods to determine what proportion of Sockeye redds and emergent fry are at risk of desiccation due to manipulation of lake levels.
- Conduct annual surveys of Hucuktlis Lake beach spawning Sockeye to ensure escapement counts are reflective of the total spawning population size.
- Continue to advance the use of an acoustic counter to enumerate adult escapements on the Hucuktlis River.

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