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Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2022/007

ESTIMATES OF BIOLOGICAL BENCHMARKS FOR THE CANADIAN-ORIGIN YUKON RIVER MAINSTEM CHINOOK SALMON STOCK AGGREGATE

Chinook Salmon (Oncorhynchus tshawytscha). Image credit: Paul Vecsei.

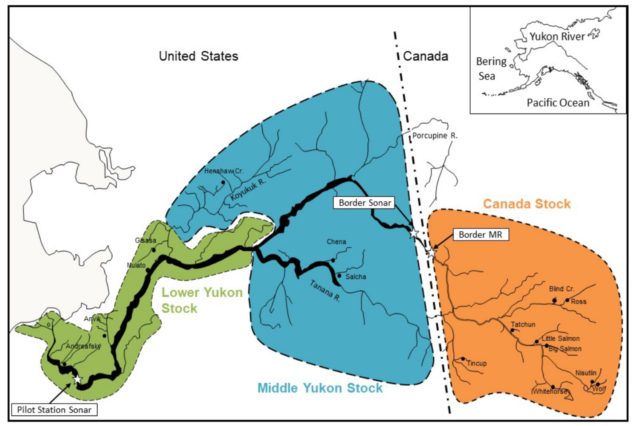

Figure 1. Yukon River drainage. Adapted from Hamazaki (2021). Colored outlines approximate spatial extent of the three stock aggregates that were modelled and individual points are assessment projects whose data were used.

Context:

In 2002, Canada and the United States confirmed the Yukon River Chapter of the Pacific Salmon Treaty (1985) where the spawning escapement goal of Canadian-Origin Yukon River Chinook was set at 33,000 to 43,000 (JTC 1987). Since then, assessment projects and associated data have become more informative and expansive resulting in variations in this spawning escapement goal over the last two decades. The Interim Management Escapement Goal is currently 42,500 to 55,000 (JTC 2021). The Joint Technical Committee (JTC) is composed of multiple Canadian and U.S. entities and provides technical support to the Yukon River Panel (Panel). In April 2019, the JTC signaled its decision to undertake a quantitative review of the Canadian-origin Chinook Salmon Interim Management Escapement Goal in response to the Panel's desire to explore the possibility of establishing a biologically based escapement goal for this stock. A bilateral working group was tasked to review available data, develop statistical models, and estimate key biological benchmarks for the purpose of informing escapement goal recommendations.

Fisheries and Oceans Canada (DFO) Treaties and Fisheries Unit, Yukon Transboundary Rivers Area, on behalf of the JTC, requested that DFO Science Branch provide advice regarding estimates of biological benchmarks for Canadian-Origin Mainstem Yukon River Chinook Salmon. This advice will be used to inform subsequent fisheries management recommendations to meet treaty and international obligations, Precautionary Approach commitments, emerging requirements under the 2019 amendments to Canada's Fisheries Act (Fisheries Act, RSC 1985, c. F-14), and the State of Alaska's Policy for the Management of Sustainable Salmon Fisheries and Policy for Salmon Escapement goals.

This Science Advisory Report is from the January 18-20, 2022 regional peer review on Estimates of Biological Benchmarks for the Canadian-origin Yukon River Mainstem Chinook Salmon Stock Aggregate. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Recognizing the extended time period that Canadian-origin Yukon River Chinook Salmon have been managed under an interim escapement goal, the Yukon River Panel sought to explore the possibility of establishing a biologically based escapement goal for the Canadian-origin Chinook Salmon stock aggregate, excluding the Porcupine River drainage. As a first step in this process, the Joint Technical Committee undertook a quantitative review and analysis of available data to estimate Canadian-origin Chinook Salmon run size and productivity.
- Commonly used biological benchmarks, and uncertainties in them, were estimated from an integrated run reconstruction and spawner-recruitment model fitted to data spanning 1981-2019 from various assessment projects that estimate in-river abundance, harvests, tributary escapements, stock-proportions, and age-composition.
- Equilibrium stock size (S_{EQ}) was estimated to be 111,131 (81,595-252,704, posterior median and 95% CRI), the spawner abundance expected to maximize long-term sustainable yield (S_{MSY}) was estimated to be 43,364 (29,764-97,664) and the spawner abundance expected to maximize recruitment (S_{MSR}) was estimated to be 70,834 (40,638-192,642). S_{Gen} was not estimated for the stock aggregate as it is only relevant at the scale of populations. Inference about expected yield and recruitment across a range of future spawning escapements along with probability profiles were estimated to inform future management decisions (Figure 4).
- These analyses provide a quantitative foundation upon which to base the development of a Canadian stock aggregate escapement goal recommendation, but they do not prescribe one. Key considerations when developing an escapement goal include defining its objectives and decision context, identifying the magnitude of acceptable risk of not meeting stated objectives, and identifying key uncertainties and trade-offs to help ground the degree of precaution that should be taken when establishing an escapement goal in the face of imperfect information.
- Female Chinook Salmon age-of-maturity, and to a lesser extent the proportion of females in the spawning population, has declined over time (Figure 5). Since expected reproductive output per spawner is a function of these quantities, accounting for these characteristics was estimated to cause an average increase in the spawner abundance expected to maximize yield (S_{MSY}) or recruitment (S_{MSR}) by up to 14% and 22%, respectively, in recent years relative to baseline results. As an emerging area of research, these results represent an initial attempt to account for time-varying demographic changes for this stock aggregate and have been identified as an area of future work.
- Uncertainties in the estimated benchmarks arise, in part, from challenges in accurately estimating total run size, harvest, and escapement for the Canadian stock aggregate. These challenges include potential biases stemming from: bycatch in marine fisheries, hatchery contributions, contributions from other Canadian stocks (Porcupine River), uncertainty of U.S. and Canadian harvest, unaccounted en route mortality, and pre-spawn mortality (Table 2). Additional uncertainties include the structural form of the assumed spawner-recruitment relationship and the spatial scale at which processes such as density dependence occur which may influence the estimation of biological benchmarks.

- Key uncertainties that relate to the management relevance of the benchmarks included biological risks of aggregate escapement goals for individual component populations of the Canadian stock aggregate, climate driven change (e.g., temperature, freshet timing, sea ice cover, disease, regime shifts), and time-varying demography that may result in the past no longer being a good predictor of the future.
- This bilateral U.S. / Canada work provides a new foundation of information that is anticipated to pay dividends and contribute to a wide range of research and management applications that would not otherwise be possible.
- Key recommendations for future work include: consequences of changes in escapement quality, consideration of biological risks to individual populations, Management Strategy Evaluation to evaluate the ability of alternative management strategies to meet a broad range of objectives in the system, and research into drivers and magnitude of en route mortality and their consequences for management advice.

BACKGROUND

In 2002, Canada and the United States confirmed the Yukon River Chapter of the Pacific Salmon Treaty (1985) where the spawning escapement goal of Canadian-Origin Yukon River Chinook was set at 33,000 to 43,000 (JTC 1987). Since then, the metrics of assessment and associated data have become more informative and expansive, resulting in variations in this spawning escapement goal over the last two decades. The Interim Management Escapement Goal is currently 42,500 to 55,000 (JTC 2021). The Joint Technical Committee (JTC) is composed of multiple Canadian and U.S. entities and provides technical support to the Yukon River Panel (Panel). In April 2019, the JTC signaled its decision to undertake a quantitative review of the Canadian-origin Chinook Salmon Interim Management Escapement Goal in response to the Panel's desire to explore the possibility of establishing a biologically based escapement goal for this stock. A bilateral working group was tasked to review available data, develop statistical models, and estimate key biological benchmarks for the purpose of informing escapement goal recommendations.

Terms of Reference

The specific objectives of the working paper were to:

1. Develop a Bayesian integrated state-space run reconstruction and spawner-recruitment model and fit it to available data.
2. Derive estimates of biological benchmarks (e.g., S_{MSY}, S_{EQ}, S_{MSR} , S_{GEN}) and associated profiles (e.g., yield and recruitment).
3. Document and examine the consequences of key data and methodological assumptions related to data weighting, biases in data, priors, and model structure.
4. Explore, to the extent possible with available data, the sensitivity of biological benchmarks to change in escapement quality (e.g., total fecundity and egg mass) over time.
5. Provide guidance on key considerations for next steps to identify an escapement goal and recommendations for future analyses and research to further develop them.

ANALYSIS

Data

A comprehensive review of available data with potential utility for reconstructing the abundance and dynamics of Canadian-origin Yukon River Chinook Salmon was undertaken as part of a complimentary effort to this modelling work (Pestal et al. In press). The data review spanned assessment projects from 1981-2019 for Chinook Salmon across the Yukon River basin, including in-river abundance (e.g., sonar, fishwheels, and mark-recapture projects), tributary escapement (e.g., weir, tower, aerial, and sonar projects), harvest estimation, and associated biological sampling (e.g., genetics and age-sex-length information for stock apportionment). The data review represents many hundreds of hours of collaboration to assemble a “one-stop-shop” for Yukon River Chinook Salmon abundance data.

Approach

An integrated state-space run reconstruction and spawner-recruitment model was developed (Figure 2) that was adapted from the multi-stock run reconstruction and state-space spawner-recruitment frameworks of Hamazaki (2021) and Fleischman et al. (2013), respectively. The model combines historical data (1981-2019) from various assessment projects that estimate in-river abundance, harvests, tributary escapements, stock-proportions, and age-composition, under a single Bayesian estimation framework. The run reconstruction component of the model reconstructs historical harvest and escapement for three Chinook Salmon stock aggregates: the lower, middle, and upper (Canada) portions of the Yukon River basin (Figure 1). The run reconstruction model component of this project produced previously unavailable and statistically defensible total run and stock-specific abundance, harvest, and escapement estimates. The key quantities estimated by the spawner-recruitment component of the model applied only to the Canada stock and includes intrinsic population productivity and the magnitude of within-stock density dependence from which biological benchmarks and inference about expected yield and recruitment can be derived. Biological benchmarks with associated yield and recruitment probability profiles were calculated.

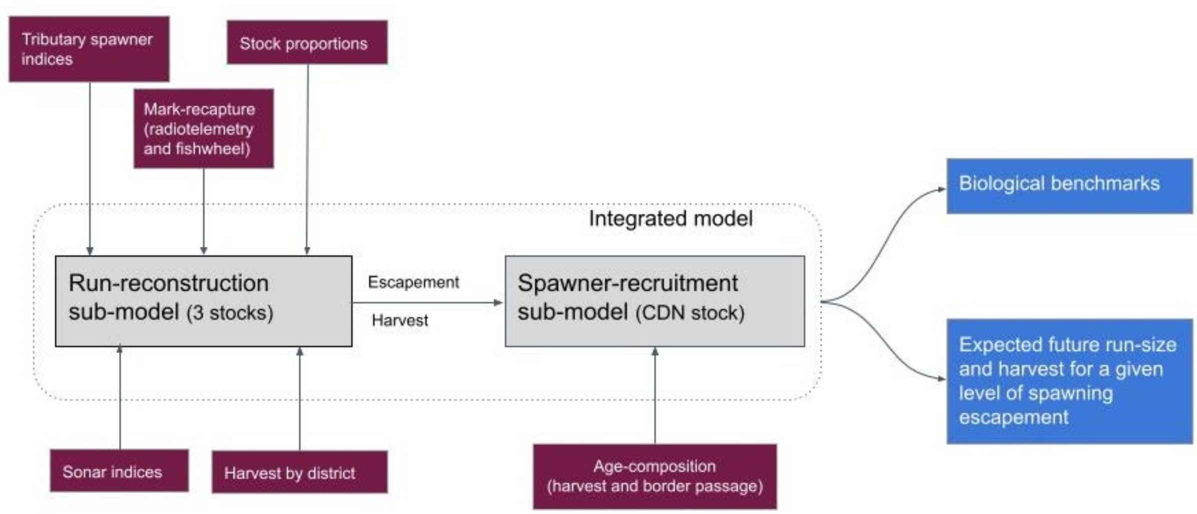

Figure 2. Schematic of the integrated model illustrating key data inputs (purple), model components (grey), and inferential outputs (blue).

Results

Model Fit

The integrated state-space run reconstruction and spawner-recruitment model had 148 parameters estimated. Diagnostic plots and statistics did not indicate any significant issues with the fit of the model to the data or the model fitting algorithm. However, model fits to upriver harvests were poor in 2017 and 2019 due to conflicting data between Pilot Sonar and Eagle Sonar. It was hypothesized that this conflict may be due, at least partially, to unaccounted natural en route mortality. Consistent with *a priori* weights for different assessment projects, model fits to tower, weir, and sonar projects were more precise than aerial and foot survey data. Excluding individual tributary assessments in Canada from the model was more impactful on estimates of Canada stock run size than excluding lower or middle US assessment projects. The fish wheel mark-recapture index of abundance was highly influential for estimated Canadian escapement because it was the only assessment of border passage operating prior to 2005.

Run-Size, Escapement and Harvest

The average basin-wide run abundance was approximately 288,000 fish per year (range of median estimates: 98,000 in 2013 to 466,000 in 1995). The Canadian portion of the Yukon was estimated to produce the largest average annual run abundances of the three stocks at approximately 124,000, followed by the lower river stock at 85,000, and then middle river stock at 64,000. All stocks experienced relatively large run abundances from 1982-1995, followed by a sharp decline (particularly for the Canada stock) with the lowest observed abundances in 2000 and 2013. In contrast to run abundance, spawning escapement abundances for all three stocks have been relatively consistent over time. Aggregate harvest and harvest by stock varied considerably over time and realized harvest rates ranged from 3-82%, 2-87%, and 26-52% for the Canada, middle, and lower stocks, respectively.

Productivity, Recruitment, Yield, and Capacity

The Canadian-origin Yukon Chinook Salmon stock aggregate is moderately productive with intrinsic productivity estimated to be 4.96 recruits per spawner (posterior median of α'; 95% credible interval [CI]: 2.66-9.98; Table 1). Recruitment anomalies were estimated to be moderately positively correlated through time (ϕ= 0.39; CI: -0.04-0.87; Table 1) and realized recruits produced per spawner was above average in the 1980s, variable in the 1990s, below average in the 2000s with several years at replacement, and has since increased back towards the long-term average in the most recent decade (Figure 3).

Table 1. Posterior means, medians and credible intervals for leading spawner-recruitment parameters and associated biological benchmarks. Also shown are estimates of the effective sample size and potential scale reduction factor ($\hat{R}$) for parameters and benchmarks estimated by the model, with values greater than 1000 (n_{eff}) and less than 1.01 ($\hat{R}$) indicating they were well estimated.

Variable	Mean	Median	P2.5	P97.5	n_{eff}	$\hat{R}$
$ln(\alpha)$	1.640	1.601	0.978	2.300	6,325	1.0001
β	1.431E-05	1.412E-05	5.191E-06	2.461E-05	5,712	1.0006
σ_R	0.444	0.439	0.318	0.602	6,136	1.0001
ϕ	0.934	0.393	-0.044	0.872	3,151	1.0009
S_{MSR}	83,088	70,834	40,638	192,642	5,758	1.0008
S_{EQ}	127,792	111,131	81,595	252,704	5,874	1.0006
S_{MSY}	48,715	43,364	29,764	97,664	6,070	1.0007
U_{MSY}	62%	62%	42%	78%	5,203	1.0008
U_{MSR}	43%	45%	1%	73%	-	-

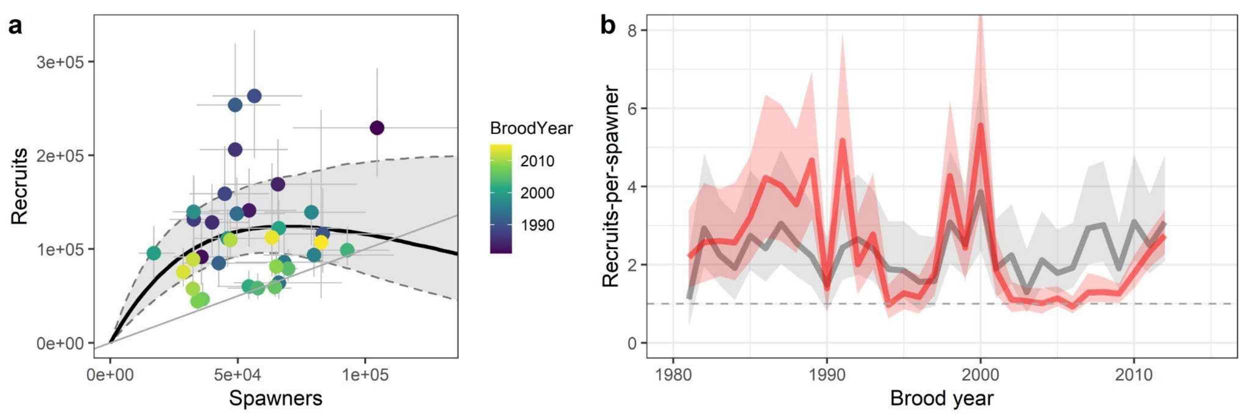

Figure 3. Spawner-recruitment relationship and productivity over time. (a) Relationship between recruitment and spawner abundance for Canada-origin Yukon Chinook Salmon from 1982 - 2019. Error bars and grey band are 95% credible intervals, thick black line is the expected relationship. (b) Realized recruits produced per spawner over time (red; median and 95% credible intervals) with dashed line at replacement. Also shown are deterministic predictions from spawner-recruitment relationship (grey; median and 95% credible intervals) to illustrate periods where realized recruits produced per spawner were greater, similar, and less than what would be predicted based on the estimated underlying spawner-recruitment relationship alone.

Equilibrium stock size (S_{EQ}), where recruitment is expected to replace spawners exactly in the absence of harvest, was estimated to be 111,131 (CI: 81,595-252,704; Table 1). The spawner abundance expected to maximize long-term sustainable yield (S_{MSY}) was estimated to be 43,364 (CI: 29,764-97,664; Table 1), while the spawner abundance expected to maximize recruitment (S_{MSR}) was estimated to be 70,834 (CI: 40,638-192,642; Table 1). Lastly, the harvest rate expected to lead to maximum sustainable yield (U_{MSY}) was estimated to be 62% (CI: 42-78%; Table 1), and the harvest rate expected to result in maximum recruitment (U_{MSR}) was estimated to be 45% (CI: 1-73%; Table 1).

There was relatively large uncertainty in leading parameters, the overall shape of the spawner-recruitment relationship, and associated biological benchmarks, as illustrated by their large credible intervals (Table 1). Therefore "optimal" yield (Figure 4a) and recruitment (Figure 4b) profiles were generated that illustrate the expected probability that a given number of spawners will achieve some percentage of maximum sustainable yield or recruitment, respectively. Figure 4 provides profiles across a range of thresholds (70%, 80%, and 90%) that could define optimal yield and recruitment, as well as yield-based risk associated with supplying too few spawners.

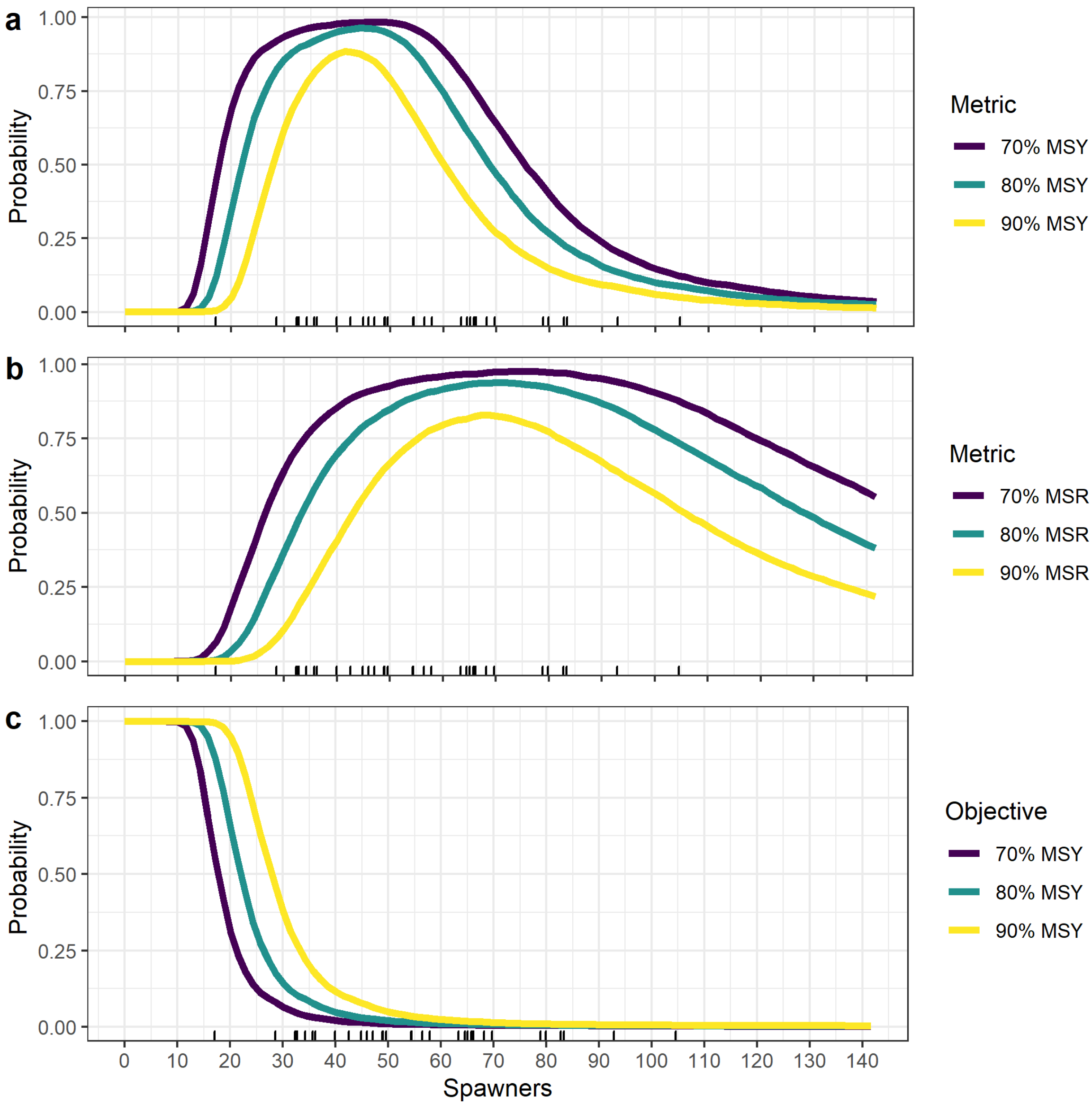

Figure 4. Optimal probability profiles for sustained yield (SY), recruitment, and "overfishing". (a) Optimal yield profile showing the probability that a given spawner abundance is expected to achieve 70%, 80%, or 90% of maximum sustainable yield (MSY). (b) Optimal recruitment profile showing the probability that a given spawner abundance is expected to achieve 70%, 80%, or 90% of maximum sustainable recruitment (S_{MSR}). (c) Overfishing profile, calculated as 1 – P(SY > X% of MSY) at S < S_{MSY} and 0 at S > S_{MSY}, showing the probability that, at a given spawner abundance, sustained yield (SY) is reduced to less than a percentage (70%, 80%, or 90%) of MSY by supplying too few spawners. On each panel, historical spawning escapements are shown as ticks along x-axis.

Escapement Quality

Female Chinook Salmon age composition, as measured at the Alaska-Yukon border, has declined over time. In the 1980s, approximately 20% of females were age-7, 70% were age-6, and fewer than 10% of females returned on average as age-5 (Figure 5c). By the 2010s, an average of 5% of females returned as age-7, 70% as age-6, and 25% as age-5. In addition, the proportion of returning fish that were female has declined over time from an average of approximately 53% in the 1980s to 44% in the 2010s, with considerable interannual variation (as high as 59% in 1989 and low as 32% in 2016; Figure 5a). In contrast to these changes in age and sex over time there was no evidence of directional change in female length at age over this same period (Figure 5b). Collectively, these observed demographic changes have resulted in declines in per capita output of eggs and total egg mass over time such that for the same number of spawners, early years produced an above average number of eggs or total egg mass, whereas recent years produced a below average number of eggs and total egg mass (Figure 5d).

As a result of these observed declines in total eggs and egg mass, the spawner abundance expected to maximize yield was estimated to be about 11% greater on average in recent years (2009-2019) than in the 1980s and was slightly greater when considering total egg mass (13%) as the units of reproductive output instead of total eggs. The consequences of declines in total eggs and egg mass were more pronounced for estimates of spawner abundance associated with maximum recruitment which was estimated to be on average about 18% greater in recent years (2009-2019) than in the 1980s and was also slightly greater when considering total egg mass (23%) as the units of reproductive output instead of total eggs.

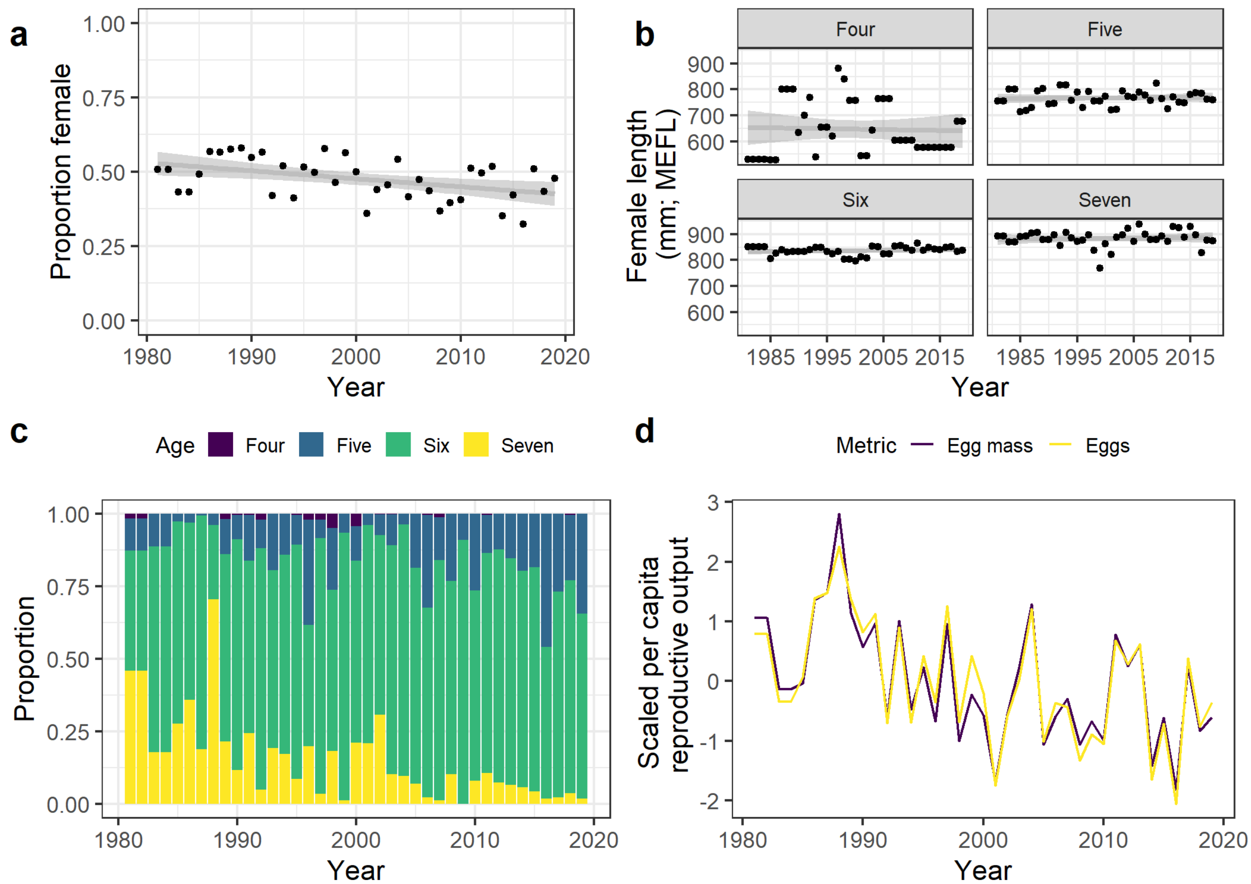

Figure 5. Female Chinook Salmon age, sex, and size composition over time and implications for reproductive output. (a) Proportion of returning Chinook Salmon that are female. (b) Average female length (mid-eye to tail fork length; MEFL) at age. (c) Proportion of females returning to spawn at age 4-7. (d) Total reproductive output where egg mass and eggs are based on the age, sex, length information in panels a-c ,length-fecundity/egg mass relationships, and estimates of total spawning escapement from the base case integrated Run-reconstruction (RR) – Spawner Recruitment Analysis (SRA) model. Years without data were infilled with the same values as the next year with data. Note: age-3 and age-8 individuals were combined with age-4 and age-7, respectively, and age-4 female lengths are based on very small sample sizes in most years and so should be interpreted with caution. However, because age-4 females make up so little of the spawning population (panel c) these estimates have little influence on time series of reproductive output.

Sensitivity Analyses

Sensitivity analyses were completed to see the influence of various data sets and model assumptions. Fits to lower river harvest and age composition data, as well as estimates of both S_{MSY} and S_{MSR}, were moderately sensitive to assumptions about age composition data weighting. Fits to the stock composition data and estimates of S_{MSY} and S_{MSR} were robust to assumptions about stock composition data weighting. Removing the observed and assumed measures of index uncertainty in the run reconstruction and allowing the model-estimated added variance terms to be the sole measure of index uncertainty had little impact on estimates of the Canadian run size. The estimated shape of the underlying stock-recruitment relationship was distinctly different between the Ricker and Beverton-Holt model formulations, with the Beverton-Holt version estimating a much more rapid increase in recruitment at low spawning abundances. This resulted in substantially lower estimates of the spawning abundance necessary to produce maximum sustainable yield as compared with the Ricker model.

Sources of Uncertainty

- Uncertainties in the estimated benchmarks arise, in part, from challenges in accurately estimating total run size, harvest, and escapement for the Canadian stock aggregate. These challenges include potential biases stemming from: bycatch in marine fisheries, hatchery contributions, contributions from other Canadian stocks (Porcupine River), uncertainty of U.S. and Canadian harvest, unaccounted en route mortality and pre-spawn mortality (Table 1).
- Additional uncertainties include the structural form of the assumed spawner-recruitment relationship and the spatial scale at which processes like density dependence occur which may influence the estimation of biological benchmarks.
- Key uncertainties that relate to the management relevance of the benchmarks included biological risks of aggregate escapement goals for individual component populations of the Canadian stock aggregate, climate driven change (e.g. temperature, freshet timing, sea ice cover, disease, regime shifts), and time-trending demography that may result in the past no longer being a good predictor of the future.

Table 2. Known and/or potential biases in the datasets used to estimate biological benchmarks for Canadian-origin Yukon River Chinook Salmon and their potential consequences. Consequences of individual biases for estimates of S_{MSY} and S_{MSR} were quantified through sensitivity analyses using a brood table derived from the median posterior estimates of harvest, escapement, and age composition from the integrated model.

KNOWN / POTENTIAL BIAS	POSSIBLE CONSEQUENCES FOR BIOLOGICAL BENCHMARKS[1]
Unaccounted bycatch in marine fisheries resulting in underestimation of total run-size	5% underestimate of total run abundance results in ~2% underestimate of S_{MSY} and no change in S_{MSR}
Unaccounted hatchery contributions resulting in overestimation of run-size	3% overestimate of run abundance overestimates S_{MSY} and S_{MSR} by ~3%
Unaccounted contribution of Porcupine River Chinook Salmon to estimates of harvest of Canadian stock in the US resulting in overestimation of harvest	7% overestimate of harvest of Canadian stock in US results in ~3% underestimate of S_{MSY} and no change in S_{MSR}
Overestimation of harvest of Canadian stock in the US District 5	10% overestimate of harvest of Canadian stock results in ~3% underestimate of S_{MSY} and no change in S_{MSR}
Unaccounted for en route and pre-spawn mortality in Canada resulting in overestimation of spawning escapement	15% overestimate of Canadian stock escapement results in ~6% overestimate of S_{MSY} and 10% overestimate in S_{MSR}

[1] The under/overestimate percentages in this table are considered upper bounds (i.e., worst case scenarios) that in most cases are greater than the likely magnitude of bias.

CONCLUSIONS

- All five objectives of the Terms of Reference were met.
- Commonly used biological benchmarks and uncertainties were estimated from an integrated run reconstruction and spawner-recruitment model fit to data from 1981-2019 from various assessment projects that estimate in-river abundance, harvests, tributary escapements, stock-proportions, and age-composition.
- Equilibrium stock size (S_{EQ}) was estimated to be 111,131 (81,595-252,704, posterior median and 95% CRI), the spawner abundance expected to maximize long-term sustainable yield (S_{MSY}) was estimated to be 43,364 (29,764-97,664) and the spawner abundance expected to maximize recruitment (S_{MSR}) was estimated to be 70,834 (40,638-192,642). S_{Gen} was not estimated for the stock aggregate as it is only relevant at the scale of populations. Inference about expected yield and recruitment across a range of future spawning escapements along with probability profiles were estimated to inform future management decisions (Figure 4).
- These analyses provide a quantitative foundation upon which to base the development of a Canadian stock aggregate escapement goal recommendation, but they do not prescribe one. Key considerations when developing an escapement goal include defining its objectives and decision context, identifying the magnitude of acceptable risk of not meeting stated objectives, and identifying key uncertainties and trade-offs to help ground the degree of precaution that should be taken when establishing an escapement goal in the face of imperfect information.
- Female Chinook Salmon age-at-maturity, and to a lesser extent the proportion of females in the spawning population, has declined over time (Figure 5). Since expected reproductive output per spawner is a function of these quantities, accounting for these characteristics was estimated to cause an average increase in the spawner abundance expected to maximize yield (S_{MSY}) or recruitment (S_{MSR}) by up to 14% and 22%, respectively, in recent years relative to baseline results. As an emerging area of research, these results represent an initial attempt to account for time-trending demographic changes for this stock aggregate and have been identified as an area of future work.
- These analyses provide a quantitative foundation upon which to base the development of a Canadian stock aggregate escapement goal recommendation, but they do not prescribe one. Key considerations when developing an escapement goal include defining the decision context and objective(s) of the escapement goal, identifying the magnitude of acceptable risk of not meeting stated objectives, and identifying key uncertainties and trade-offs to help ground the degree of precaution that should be taken when establishing an escapement goal in the face of imperfect information.
- This bilateral U.S. / Canada work provides a new foundation of information that is anticipated to pay dividends and contribute to a wide range of research and management applications that would not otherwise be possible. The data review report represents many hundreds of hours of collaboration to assemble a “one-stop-shop” for Yukon River Chinook Salmon abundance data. The run reconstruction model component of this project produced previously unavailable total run, harvest, and escapement estimates for all three major Yukon River Chinook Salmon stock aggregates.
- The analyses presented in the working paper benefited from a rich diversity of long-term assessment data from throughout the Yukon River Basin without which biological benchmarks could not be estimated. However, there were several uncertainties (e.g., en route mortality in Canada) that could not be resolved due to a lack of long-term and

contemporary tributary level assessment data in Canada. This lack of data underscores the importance of carefully considering opportunities to improve future tributary-level assessments of Chinook Salmon in Canada.

- Key recommendations for future work include: consequences of changes in escapement quality, consideration of biological risks to individual populations, Management Strategy Evaluation to evaluate the ability of alternative management strategies to meet a broad range of objectives in system, and research into drivers and magnitude of en route mortality and their consequences for management advice.

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SOURCES OF INFORMATION

This Science Advisory Report is from the January 18-20, 2022 regional peer review on Estimates of Biological Benchmarks for the Canadian-origin Yukon River Mainstem Chinook Salmon Stock Aggregate. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Fleischman, S.J., Catalano, M.J., Clark, R.A., and Bernard, D.R. 2013. An age-structured state-space stock–recruit model for Pacific salmon (*Oncorhynchus* spp.). Can. J. Fish. Aquat. Sci. 70(3): 401–414.

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Pestal, G., Mather, V., West, F., Liller, Z., and Smith, S. (In press). Review of available abundance, age, and stock composition data useful for reconstructing historical stock specific runs, harvest, and escapement of Yukon River Chinook salmon (*Oncorhynchus tshawytscha*), 1981-2019. Fisheries and Oceans Canada Technical Report.

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