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FRAMEWORK FOR DETERMINATION OF PACIFIC SALMON COMMISSION REFERENCE POINTS FOR STATUS DETERMINATION AND ASSOCIATED ALLOWABLE EXPLOITATION RATES FOR SELECT CANADIAN SOUTHERN COHO SALMON MANAGEMENT UNITS

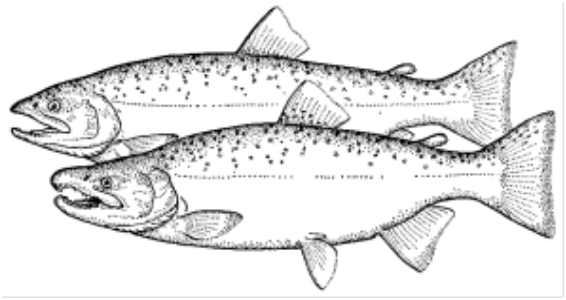

Figure 1. Coho Salmon — provided by Fisheries and Oceans Canada, Freshwater Fishes of Canada, 1973 Fisheries Research Board of Canada, Bulletin 184, Catalogue No. FS94-184, Page 158 – line drawing of Coho Salmon.

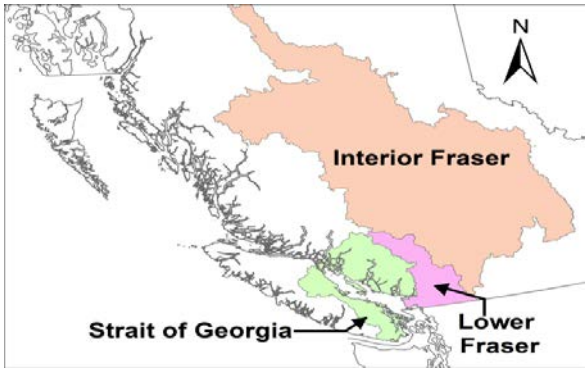

Figure 2. Map of the four Canadian Southern Coho Salmon Management units (prior to 2018). Adapted from Report TCCOHO(13)-1 (http://www.psc.org/).

Context:

The Pacific Salmon Treaty (PST) provides the framework through which Canada and the United States work together to conserve and manage Pacific salmon. The objective of the bilateral Canada/US Southern Coho Management Plan, outlined in Annex IV, Chapter 5 of the PST, is to manage total fishery exploitation to enable management units to produce Maximum Sustainable Harvest over the long term, while maintaining the genetic and ecological diversity of the component populations and to improve long-term prospects for sustaining healthy fisheries in both countries. In order to help meet this objective, the management plan also requires the development of MU-specific management reference points for a range of status categories, as well as associated exploitation rates that achieve the management goals set out in Annex IV, Chapter 5.

The current Pacific Salmon Treaty (PST) identifies four Southern BC Coho management units (MU): Interior Fraser (including Thompson), Lower Fraser, Strait of Georgia Mainland, and Strait of Georgia Vancouver Island. To date, there is no commonly accepted method available to derive management reference points and associated exploitation rates for MUs that lack escapement data time series. Presently, Interior Fraser is the only Canadian Coho Salmon MU where comprehensive escapement data have been collected and biological abundance-based benchmarks have been established.

Fisheries and Oceans Canada (DFO) Fisheries Management branch has requested that Science Branch provide benchmarks to inform the development of management reference points for all Canadian Southern BC Coho MUs.

This Science Advisory Report is from the September 20-21, 2017 regional peer review on the determination of reference points for status determination and associated allowable exploitation rates for Canadian PST Southern Coho Management Units. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- In order to fulfill obligations to the bilateral Canada/US Southern Coho Management Plan (Pacific Salmon Treaty, Annex IV, Chapter 5), DFO Fisheries Management branch requested that DFO Science Branch provide biologically-based benchmarks across a range of status categories to inform the determination of management reference points and associated allowable exploitation rate targets for all Canadian Southern BC Coho management units (MUs).
- *Biological benchmarks* demarcate categories of population status based on conservation and production considerations. For example, biological benchmarks used to assess population status of Interior Fraser Coho conservation units were based on several of the conservation objectives outlined in appendix A.
- *Management reference points (*also called *operational control points)* incorporate biological, economic and policy considerations to demarcate population levels triggering specified management actions. In the current context, management reference points could be derived from this process to define Pacific Salmon Treaty status categories (low, moderate and abundant) and propose associated allowable exploitation rates to guide management of the Canadian Southern BC Coho MUs.
- To date, there is no commonly accepted method available to derive status benchmarks for MUs that lack reliable escapement data time series. Presently, Interior Fraser is the only Canadian Coho Salmon MU where extensive escapement data have been collected and biological abundance-based benchmarks have been established based on the work of the Interior Fraser Coho Recovery Team (IFCRT) and Wild Salmon Policy integrated biological status assessment processes. It is well documented that a considerable number of potential biases and uncertainties are associated with these data.
- This assessment focuses on evaluating the effects of exploitation rate changes on meeting conservation objectives across a range of smolt-to-adult survival rates that can be used to define status across three Pacific Salmon Treaty (PST) status categories: low, moderate, abundant. To do this, a range of stock-recruitment (S-R) models were fit using Bayesian estimation procedures that incorporated hatchery smolt-adult survival as a surrogate for population productivity. The resulting parameter estimates are then used to conduct both retrospective and forward simulations.
- Retrospective simulations were used to examine the historical pattern in escapement to each Interior Fraser Coho (IFC) conservation unit (CU) under different assumed exploitation histories and assumed S-R dynamics. Subsequently, forward simulations populated with estimates derived from the Bayesian S-R analyses were used to determine expected conservation performance (i.e., the mean probability of meeting previously established conservation benchmarks) over a 50-year time frame, and across a range of exploitation and smolt-to-adult survival rates.
- S-R parameters were derived for the individual IFC CUs, the IFC MU as a whole and the Strait of Georgia (SOG) MU, as represented by the Black Creek indicator stock. No S-R analysis was conducted for the lower Fraser River (LFR) MU due to a lack of suitable data. Retrospective and forward simulations were completed for the IFC MU, resulting in a set of decision tables that can be used to inform the selection of status benchmarks and management reference points using hatchery survival as an index of productivity. Due to lack of data, comparable analyses for the SOG and LFR MUs are not possible at this time.

- Examples are provided to illustrate how the results from this framework could be used to inform the development of management reference points for setting low, moderate and abundant status categories under the PST; formal recommendations on reference points to use for management purposes are not provided. The selection of these reference points will require input from government, First Nations, and stakeholders on acceptable probabilities of achieving conservation outcomes given the uncertainties.
- Given the uncertainties associated with the S-R data, there are several model forms that might be used to represent true underlying Coho population dynamics. In the context of this analysis, the choice of S-R model would influence the estimation of exploitation and smolt-to-adult survival rates, as well as the resulting assessments of future conservation performance.
- Inherent uncertainties and potential inter-annual biases in the available data ultimately leads to wide credible intervals around the estimated probabilities of achieving stated conservation objectives obtained through the forward simulations. For example, errors in estimation of realized exploitation rates (as a result of under- or unreported catch) and annual escapement estimates, along with necessary assumptions about underlying population dynamics all contribute considerable uncertainty and potential inter-annual biases to the estimates.
- The present simulation results are based on natural production only. If the current levels of CU-specific hatchery production were included in the model, hatchery fish spawning in the wild would contribute to the production of natural-origin fish, resulting in an increase to the modeled estimate of conservation performance.
- To capitalize on opportunities to update and improve this analysis as identified through this review (e.g, adding a freshwater survival covariate to the S-R models to account for sources of inter-annual and inter-population variation), periodic review and update of this assessment is recommended as new information and data becomes available.

INTRODUCTION

The Pacific Salmon Treaty (PST) provides the framework through which Canada and the United States work together to conserve and manage Pacific salmon. Objectives of the bilateral Canada/US Southern Coho Management Plan, outlined in Annex IV, Chapter 5 of the PST, include the management of total fishery exploitation to enable management units (MU) to produce Maximum Sustainable Harvest (MSH) over the long term, while maintaining the genetic and ecological diversity of the component populations and improving long-term prospects for sustaining healthy fisheries in both countries. Conventional approaches for determining appropriate PST status reference points and target exploitation rates rely on accurate estimates of catch and escapement, which are lacking for most Coho Salmon populations in BC. Therefore, this work proposes an assessment method using smolt-to-adult survival time series (rather than measures of absolute abundance) to establish reference points that can be used to guide management of southern BC Coho Salmon.

It is important to note the distinction between *biological benchmarks* and *management reference points* (also called *operational control points*). Biological benchmarks demarcate categories of population status based on conservation and production considerations. For example, biological benchmarks used to assess population status of Interior Fraser Coho conservation units were based on several of the conservation objectives outlined in Appendix A. Conversely, management reference points (operational control points) incorporate biological, economic and

policy considerations to demarcate population levels triggering specified management actions. In the current context, management reference points could be derived from this process to define Pacific Salmon Treaty status categories (low, moderate and abundant) and propose associated allowable exploitation rates to guide management of the Canadian Southern BC Coho MUs.

ASSESSMENT

Data

Currently, the PST identifies four Southern BC Coho management units (MUs): Interior Fraser River (including Thompson), Lower Fraser, Strait of Georgia Mainland, and Strait of Georgia Vancouver Island. An updated Annex IV, Chapter 5 is expected to be ratified in 2018 for implementation beginning in 2019, and it is proposed that the Strait of Georgia Mainland and Strait of Georgia Vancouver Island MUs be combined into one Strait of Georgia MU. Thus, results provided here are based on the three MUs defined in the pending PST agreement: Interior Fraser Coho (IFC), Lower Fraser River (LFR) and Strait of Georgia (SOG) MUs. Each MU presents a different combination of data availability and quality, necessitating modified analytic approaches for each.

The IFC MU provides the most comprehensive escapement data time series of the three MUs being assessed. Updated escapement data time series for the five constituent Conservation Units (CUs) [Middle Fraser (MF), Fraser Canyon (FC), Lower Thompson (LT), North Thompson (NT), South Thompson (ST)] were used to provide current (natural-origin) recruitment, smolt-to-adult survival and exploitation rate estimates. Unlike the fixed age structure approach used in other recent IFC assessments (i.e., Decker et al. 2014; Parken et al., unpublished data[1], COSEWIC 2016), a method to calculate brood-year specific age composition was devised and implemented. This helps to account for differences in age composition of individual broods over time, owing mainly to differences in cohort size, and also avoids an overestimation of productivity in the reconstructed abundance of smaller broods. Indices of smolt-to-adult survival rates of interior Fraser hatchery releases were used as a surrogate for smolt-to-adult survival for naturally produced Coho Salmon in the stock-recruitment analysis.

For the SOG MU, the Black Creek indicator stock was used to provide the annual escapement and modeled exploitation rate and marine survival estimates to estimate recruitment. The Strait of Georgia hatchery survival index (based on average annual smolt-to-adult survival estimates for Big Qualicum and Quinsam hatcheries) was used to represent smolt-to-adult survival for this MU. Note that, although there is a smolt-adult survival rate time series for Black Creek available at present, funding to continue monitoring this wild index stream is uncertain, and as such, was not used in this SOG S-R analysis.

For the Lower Fraser MU, S-R and simulation analyses (retrospective or forward-projecting) were not conducted due to a lack of suitable data (recent escapement data time series or a representative smolt-to-adult survival index). Note that, although there is a time series of data for the Inch Creek Hatchery that could represent smolt-to-adult survival, without estimates of natural origin escapement in the LFR MU, the hatchery index cannot be used singularly to establish status.

[1] Parken, C.K. and 20 co-authors. CSAP Working Paper 2013SAL12. Wild Salmon Policy Biological Status Assessment for Conservation Units of Interior Fraser River Coho Salmon (*Oncorhynchus kisutch*).

Stock-Recruitment Analysis

For each CU in the IFC MU, a range of stock-recruit models (see Appendix A) with a smolt-to-adult survival covariate were fit using a hierarchical Bayesian modeling (HBM) approach, including a hyper-distribution parameter to model the covariation among CUs in a given year. A MU-level stock-recruit model was also fit. A number of derived parameters and biological benchmarks based on the mean estimates of the stock-recruit parameters were then calculated, including the escapement needed to maximize sustainable yield (S_{msy}), the escapement needed to reach S_{msy} in one generation (S_{gen}), the equilibrium escapement in the absence of harvest (S_{eq}), the escapement that maximizes recruitment (S_{max}), and the harvest rate at maximum sustainable yield (U_{msy}).

A similar stock-recruit modeling approach was used for the Strait of Georgia MU, though it was not necessary to include a hyper-distribution parameter in the Bayesian modelling procedure because the data were from a single population (Black Creek).

No stock-recruitment analysis was conducted for the Lower Fraser MU.

Historical Reconstruction (Retrospective Simulation)

A retrospective analysis was used to simulate what escapement patterns would have looked like under historical conditions but with alternative exploitation histories. For both the IFC and SOG MUs, simulations were first run with historical exploitation rates to verify the predicted escapements matched the observed trends. The simulations were then re-run three times for each MU: with fixed exploitation rates of 0 (representing no exploitation), a value close to the mean exploitation rate over the period simulated, and a third rate representing a theoretical upper bound for exploitation rate (i.e. 0/10/30% for IFC MU and 0/5/30% for SOG MU). As stated previously, no simulations were run for the LFR MU. Simulations were run using S-R parameter estimates from the base Ricker S-R model form (which provided the best statistical fit to the available data), and only modeled natural production (i.e., simulations did not account for hatchery-origin fish spawning in the wild that subsequently contribute to natural recruitment). Further, potential effects of implementation error (the difference between target and realized exploitation rate) were not included in the retrospective analyses.

Exploitation Rate Analysis (Forward Simulation)

As a final step, the effects of alternate exploitation rates and future smolt-to-adult survival on escapement for each IFC CU were evaluated using a 50-year forward simulation (2016-2065). Conservation Objectives used in this analysis were derived from previous work conducted by the IFCRT (IFCRT 2006; see Appendix A for definitions used here).

In each year of the simulation, 3-year geometric mean escapements from each CU (IFC MU) were compared to published conservation objectives (see Appendix A for details) to determine the overall frequency of years in which the objectives were reached. The model simulated smolt-to-adult survival rates ranging from 0.0025 to 0.1 and exploitation rates ranging from 0 to 0.7. The model simulated variation in recruitment among years using the estimates of residual variation observed around the S-R curve (see Appendix A for the S-R model forms used in the results). It also simulated exploitation rate implementation error based on an estimate of annual exploitation rate targets versus estimated realized exploitation rates in the historical time series.

Results

IFC MU

For the IFC MU and using the base Ricker S-R model form, productivity (adult recruits/spawner at low stock size) ranged from about 2.2-2.6 recruits/spawner across CUs, resulting in exploitation rates that maximized yield (U_{msy}) of 0.36-0.42. Further, the hatchery smolt-to-adult survival rate index predicted an additional 18-28% of the variation in productivity across IFC CUs and thus was demonstrated to be useful for assessing changes to the status of the IFC CUs and MU.

For the Ricker model with an assumed higher carrying capacity (Ricker-PriorCap), which eliminated over-compensatory dynamics, the productivity (adult recruits/spawner at low stock size) ranged from about 1.7-2.1 recruits/spawner across CUs, resulting in exploitation rates that maximized yield (U_{msy}) of 0.26-0.34.

For the Ricker model with an assumed higher carrying capacity and depensation effect (Ricker-Dep), the productivity (adult recruits/spawner at low stock size) was 0.0 recruits/spawner across CUs, resulting in exploitation rates that maximized yield (U_{msy}) of 0.19-0.32.

Subsequently, the retrospective analysis for the IFC MU (using the base Ricker model) demonstrated that the historical average exploitation rate since the 1998 fishery closure (11%) has only marginally increased escapements relative to what might have occurred under an average targeted exploitation rate of 20%.

The forward simulations quantified conservation performance over a range of exploitation and smolt-to-adult survival rates for the IFC MU. Decision tables arranged by S-R model form (3 variations) and conservation objective (3 variations) are provided in Appendix B.

SOG MU

The S-R analysis for the SOG MU was based on escapement data for Black Creek and the Strait of Georgia hatchery survival index. Productivity of Black Creek, based on the basic Ricker S-R model form and an average smolt-to-adult survival index for the SOG hatchery indicator stock (averaging 0.84% since 1998), was 2.9 recruits per spawner, with an associated U_{msy} of 0.46. These results declined to 2.5 and 0.40, respectively, when a Ricker S-R model with higher carrying capacity (and thus, no overcompensation) was used (i.e., Ricker-PriorCap). Results based on the Ricker-Dep model were 0.0 and 0.47 respectively.

Retrospective and forward simulation assessments of conservation performance were not possible for the SOG MU due to a lack of established conservation benchmarks and S-R data from a sufficient number of populations in each of the three constituent CUs (Georgia Strait Mainland, East Vancouver Island – Georgia Strait and Howe Sound – Burrard Inlet). This assessment suggests that Black Creek may be representative of intensively studied coastal Coho Salmon populations (i.e., given that its estimated productivity is similar to the mean of 16 coastal Coho Salmon populations presented in Korman and Tompkins 2014), but there is no data describing the variation in productivity across populations in the SOG MU (i.e., at present, it is unknown how well Black Creek represents the SOG MU as a whole). A plausible conclusion that can be drawn from this analysis for the SOG MU is that, assuming a smolt-to-adult survival rate close to the historical average (since 1998; $\bar{x}$=1%, sd = 0.00486), exploitation rates of 30% or less are unlikely to result in overexploitation of SOG Coho Salmon populations represented by the Black Creek indicator stock.

LFR MU

Comparable S-R analyses or simulation results for the LFR MU are not possible at this time due to a lack of recent, suitable quality data. Qualitatively, the trend in smolt-to-adult survival rate for the SOG hatchery indicator stock is similar to those for LFR and IFC, lending some support for assuming that the status of populations in the LFR MU are similar to those from SOG and IFC MUs. However, without S-R data or established conservation objectives, no statements about the effect of various exploitation rates on conservation can be made.

Sources of Uncertainty

Inherent uncertainties and potential inter-annual biases in the available data ultimately leads to wide credible intervals around the estimated probabilities of achieving stated conservation objectives obtained through the forward simulations. For example, errors in estimation of realized exploitation rates (as a result of under- or unreported catch) and annual escapement estimates, along with necessary assumptions about underlying population dynamics all contribute considerable uncertainty and potential inter-annual biases to the estimates. Similar concerns have been noted in other analyses of southern BC Coho Salmon (Decker et al. 2014; DFO 2014). It is recommended that research to improve estimates of exploitation be prioritized and the findings incorporated into future iterations of this work (e.g., Patterson et al. 2016; Luedke et al.[2]; Parken et al.[3]).

Although the utility of including a smolt-to-adult survival co-variate in the current stock-recruit analyses was demonstrated through this work, it reflects current productivity and fishery states and will not be robust to future regime changes, should they occur. The present lack of S-R data at low escapement levels (for any CU or MU) leads to considerable uncertainty in the estimation of productivity (i.e., the initial slope of the S-R curve at lower spawner abundances). This uncertainty then carries over into the forward simulations, where it is reflected in wide confidence bands around projected conservation performance success rates.

There are potential risks to achieving management objectives when stock recruit models are applied to large population complexes (comprised of a number of independent populations or non-independent meta-populations, such as the IFC and SOG MUs). There will be a trade-off between maximizing yield and maintaining diversity when there are a diverse group of populations under a single analytical or management regime.

It is important to note that the present simulation results are based on natural production only. If the current levels of CU-specific hatchery production were included in the forward simulation models, hatchery fish spawning in the wild would contribute to the production of natural-origin fish, resulting in an increase in the model estimate of conservation performance.

There is insufficient data currently available to provide similar advice on the current status of the LFR MU. Historical data from the Salmon River (Langley) could contribute to the development of a management tool for this MU, although this would require significant investment of time and program resources.

[2] Luedke, W. et al. CSAP Working Paper 2013SAL05. Evaluation of Marine Recreational Coho Mark Selective Fisheries in British Columbia, including an evaluation of the Canadian marine fishery exploitation model for Interior Fraser Coho.

[3] Parken, C.K. et al. CSAP Working Paper 2014SAL10. Estimation of Interior Fraser River Coho Salmon Mortalities in Fraser River Fisheries (Decay Model), 2001-2014.

CONCLUSIONS AND ADVICE

This analysis is intended to evaluate potential management implications of alternative approaches for setting management reference points to establish low, moderate and abundant status zones under the PST and associated allowable fishery exploitation rates.

The S-R and simulation-based methods described in this assessment provide a useful means to inform decision makers of the relationships between productivity, exploitation rates, and ability to meet policy-driven objectives for fishery management for the IFC MU. Given limitations of the available data, the methods are sufficiently robust to examine effects of uncertainty and produce information to help evaluate implications for consideration of alternative fishery exploitation rates and risks to achieving conservation objectives. At this time, no analytically derived method to define smolt-to-adult survival rate management reference points to demarcate low, moderate and abundant PST status categories has been established, although visually the data suggest breakpoints of 2% and 4% to demarcate the three status levels. In addition, no recommendation is provided on the selection of associated fishery exploitation rates associated with each PST status category.

The likelihood of achieving a suite of conservation objectives across a range of smolt-to-adult survivals and fishery exploitation rates for IFC has been provided through a series of tables (one table for each combination of assumed S-R dynamics and conservation objective), a condensed version of which can be found in Appendix A. By selecting an appropriate S-R dynamics model (table version), hatchery smolt-to-adult survival rate (table row) and level of acceptable conservation performance (cell value), the associated exploitation rate (table column) can be determined. It is critical to note that this assessment of conservation performance is particularly sensitive to changes in exploitation rate at low smolt-to-adult survival rates, and that the inherent data uncertainties are likely too large to fully discern these sensitivities at this time (i.e., when smolt-to-adult survival rates are less than 1%).

Given the uncertainties associated with the S-R data, there are several S-R model forms that might be used to represent true underlying Coho Salmon population dynamics (Appendix A, Figure 3). In the context of this analysis, the choice of S-R model influences the estimation of exploitation and smolt-to-adult survival rates, as well as the resulting forward simulations of potential conservation performance. As a result, determination of management reference points and allowable fishery exploitation rates cannot be determined solely from the scientific advice provided here. Ultimately, the choice of management reference points and associated allowable fishery exploitation rates will require input from government, First Nations and stakeholders on acceptable probabilities of achieving conservation outcomes given the known data gaps and uncertainties.

At this time, it is not possible to use the forward simulation tool on data-limited MUs (e.g., SOG and LFR MUs), and it would take a considerable investment of time and program funds to re-instate or establish suitable indicator stocks and smolt-to-adult survival indices. In the short term, additional work is recommended to investigate the extent to which IFC CUs with similar productivities could be used to represent the data-limited MUs. Further, a comprehensive sensitivity analysis is recommended to better understand how sensitive the S-R parameters are to changes in the underlying population dynamics.

Other sources of data were suggested for use in this analysis during the peer review, but it was ultimately determined that this analysis already utilizes the best available data. A number of data limitations and assumptions were identified. Key sources of uncertainty and bias include:

- Exploitation rates: uncertainty about how representative the base period is to the current period given substantial changes in fisheries (e.g., from Coho-directed fisheries to release of wild fish in most areas); unreported catch, drop-off and release mortality not fully accounted for.
- Escapement data: survey qualities vary over time and space; only relative measures of abundance (rather than true abundance) are available for some streams.
- Hatchery smolt-to-adult survival: sample size of recovered marked fish is insufficient to give accurate estimates of the proportion of hatchery fish present; potential for hatchery fish to stray to unenhanced streams; representativeness of hatchery smolt-to- adult survival indices for wild stocks; uncertain numbers of coded wire tags (CWTs) released, due to predation after tagging but prior to release.
- Stock-recruit relationship: biases in escapement and exploitation rate time series carry forward to the S-R analysis, affecting the ability to fit and select a suitable model.

These sources of uncertainty are also suspected to vary in direction and magnitude between populations and across years. As such, it is recommended that the assumptions and findings of this assessment be re-evaluated as new research becomes available, in particular with respect to estimation of in-river and marine exploitation rates and smolt-to-adult survival indices.

SOURCES OF INFORMATION

This Science Advisory Report is from the September 20-21, 2017 regional peer review and November 6, 2017 editorial board follow-up meeting on the determination of reference points for status determination and associated allowable exploitation rates for Canadian PST Southern Coho Management Units. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Decker, A.S., Hawkshaw, M.A., Patten, B.A., Sawada, J., and Jantz, A.L. 2014. Assessment of the interior Fraser Coho salmon (*Oncorhynchus kisutch*) management unit relative to the 2006 conservation strategy recovery objectives. DFO. Can.Sci.Advis.Sec.Res.Doc . 2014/086. xi + 64 p.

DFO. 2014. Assessment of the interior Fraser River Coho Salmon Management Unit. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/032.

IFCRT (Interior Fraser Coho Recovery Team). 2006. Conservation strategy for Coho Salmon (*Oncorhynchus kisutch*), interior Fraser River populations. Fisheries and Oceans Canada, Ottawa, Ont. 132 p.

Korman, J. and Tompkins, A. 2014. Estimating regional distributions of freshwater stock productivity, carrying capacity, and sustainable harvest rates for Coho salmon using a hierarchical Bayesian modelling approach. DFO.Can. Sci. Advis. Sec. Res. Doc. 2014/089. vii + 53 p.

Patterson, D.A., Robinson, K.A., Raby, G.D., Bass, A.L., Houtman, R., Hinch, S.G., and Cooke, S.J. 2017. Guidance to Derive and Update Fishing-Related Incidental Mortality Rates for Pacific Salmon. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/011. vii + 56 p.

APPENDICES

APPENDIX A. GUIDANCE TO APPLY THE ASSESSMENT FRAMEWORK

A.1. Select a stock-recruitment model

Select a stock-recruitment model that is appropriate for the population of interest. Of the six S-R models considered in this assessment, three were determined to be most informative for Southern BC Coho MUs (Figure 3). Users of the conservation performance decision tables can choose from the following:

1. **Ricker**: This model includes a hatchery smolt-adult survival rate index covariate, and does not restrict the population dynamics in any way (via informative priors to the Bayesian analysis). This means that effects like overcompensation and depensation will be fully estimated by the available stock-recruitment data (since 1998).
2. **Ricker-PriorCap**: This model includes a hatchery smolt-to-adult survival rate index covariate and an informative prior for larger carrying capacity, effectively eliminating any form of overcompensation dynamics over the range of escapements that have been observed since 1998.
3. **Ricker-Dep**: This model includes a hatchery smolt-to-adult survival rate index covariate and informative priors for both larger carrying capacity and depensation, which reduces productivity by half when escapement levels drop below 1000 fish and eliminates any form of overcompensation over the range of escapements that have been observed since 1998.

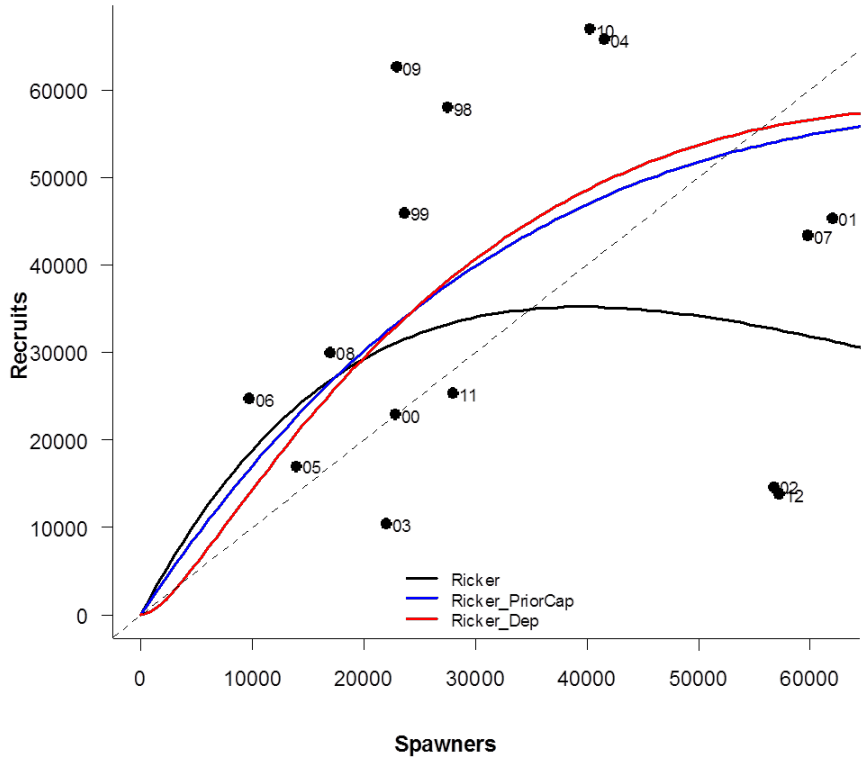

Figure 3. Comparison of three alternate Ricker stock-recruitment models for the IFC MU.

A.2. Select a conservation objective

Select an appropriate conservation objective for the population under consideration (this defines "conservation success" in the forward simulation). A number of potential conservation objectives were adapted from the IFC conservation strategy (IFCRT 2006) for this work. Users of the conservation performance decision tables can consider the following:

1. ConObj1.5: The proportion of years where ConObj1 is achieved simultaneously (within the same year) in all CUs of the MU, where ConObj1 is the escapement to each CU that leads to a 95% probability that escapement to ***at least half*** the subpopulations in the CU will meet or exceed 1,000 spawners (CU-specific Recovery Objective 1; IFCRT 2006).) This is approximately equivalent to an MU-level conservation objective of exceeding 25,000 spawners.
2. MU>20K (MU-low): The proportion of years where total escapement to the MU exceeds 20,000 spawners. (IFCRT short-term MU-level Recovery Objective; IFCRT 2006)
3. MU>40K (MU-high): The proportion of years where total escapement to the MU exceeds 40,000 spawners. (IFCRT long-term MU-level Recovery Objective; IFCRT 2006)

A.3. Select acceptable level of risk and reference the associated exploitation rate

Use the following table to find the appropriate conservation performance decision table in Appendix B.

Table 1. Reference table for selecting conservation performance decision table (Appendix B).

	Conservation Objective		
S-R Model	ConObj1.5	MU>20K	MU>40K
Ricker	Table B2.1	Table B2.1	Table B3.1
Ricker-PriorCap	Table B2.2	Table B2.2	Table B3.2
Ricker-Dep	Table B2.3	Table B2.3	Table B3.3

Example: Based on selection of the “Ricker-Dep” S-R model and conservation objective “MU>20K”, conservation performance Table B2.3 should be referenced (shaded grey above). Using the assumed hatchery smolt-to-adult survival rate (table column) and an acceptable level of risk (cell value), use the corresponding table row to identify the associated allowable exploitation rate.

Example A: Using Table B2.3, if it is decided that smolt-to-adult survival is close to the time series average (1.1%) and meeting the conservation objective 75% of the time over the 50 year forward simulation period is acceptable (i.e., 38 years out of 50, on average), then the corresponding exploitation rate is 0 (i.e., no harvest can occur).

Example B: Marine hatchery smolt-to-adult survival will need to be 2.0% in order to meet the conservation objective 75% of the time with a corresponding exploitation rate of roughly 0.075 (found by interpolating between the two yellow-shaded cells with bolded values in Table B2.3).

Example C: If a less precautionary approach is considered acceptable (i.e., if it is acceptable to meet the conservation objective in approximately half of the years simulated), the same scenario in Example A could result in a chosen allowable exploitation rate of approximately 0.1. Note that the 75% probability outcome lies within the confidence interval (see bold text, green shaded cell in Table B2.3).

APPENDIX B. CONSERVATION PERFORMANCE DECISION TABLES

Table B1.1. S-R model: base Ricker; Conservation Objective: ConObj1.5. Note this is a subset of the full tables that appear in the Research Document.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0.06 (0-0.2)	0.42 (0.02-0.84)	0.78 (0.48-0.98)	0.92 (0.8-1)	0.96 (0.92-1)	0.97 (0.94-1)	0.97 (0.94-1)	0.98 (0.94-1)	0.97 (0.92-1)	0.97 (0.92-1)
0.05	0.04 (0-0.12)	0.33 (0-0.78)	0.71 (0.34-0.96)	0.89 (0.74-0.98)	0.96 (0.9-1)	0.97 (0.92-1)	0.97 (0.92-1)	0.97 (0.94-1)	0.97 (0.94-1)	0.97 (0.92-1)
0.1	0.03 (0-0.06)	0.24 (0-0.64)	0.62 (0.18-0.92)	0.84 (0.62-0.98)	0.95 (0.88-1)	0.97 (0.92-1)	0.97 (0.92-1)	0.97 (0.94-1)	0.97 (0.92-1)	0.97 (0.92-1)
0.15	0.02 (0-0.04)	0.17 (0-0.48)	0.51 (0.08-0.86)	0.77 (0.48-0.96)	0.93 (0.84-1)	0.96 (0.92-1)	0.97 (0.92-1)	0.97 (0.92-1)	0.97 (0.92-1)	0.97 (0.92-1)
0.2	0.01 (0-0.04)	0.1 (0-0.32)	0.39 (0.02-0.78)	0.67 (0.28-0.92)	0.91 (0.78-0.98)	0.95 (0.88-1)	0.97 (0.92-1)	0.97 (0.92-1)	0.97 (0.94-1)	0.97 (0.94-1)
0.25	0.01 (0-0.02)	0.06 (0-0.16)	0.27 (0-0.64)	0.55 (0.14-0.86)	0.86 (0.68-0.98)	0.94 (0.84-1)	0.96 (0.9-1)	0.96 (0.92-1)	0.97 (0.92-1)	0.97 (0.92-1)
0.3	0 (0-0.02)	0.03 (0-0.08)	0.16 (0-0.44)	0.41 (0.04-0.78)	0.79 (0.52-0.96)	0.91 (0.78-1)	0.94 (0.88-1)	0.96 (0.9-1)	0.97 (0.92-1)	0.97 (0.92-1)
0.35	0 (0-0)	0.02 (0-0.06)	0.08 (0-0.24)	0.26 (0-0.58)	0.66 (0.28-0.92)	0.85 (0.64-0.98)	0.92 (0.82-1)	0.94 (0.86-1)	0.96 (0.9-1)	0.97 (0.92-1)
0.4	0 (0-0)	0.01 (0-0.04)	0.04 (0-0.12)	0.14 (0-0.38)	0.5 (0.1-0.86)	0.75 (0.42-0.96)	0.86 (0.66-0.98)	0.91 (0.8-1)	0.95 (0.88-1)	0.96 (0.9-1)
0.45	0 (0-0)	0.01 (0-0.02)	0.02 (0-0.06)	0.06 (0-0.18)	0.31 (0.02-0.66)	0.59 (0.18-0.9)	0.77 (0.44-0.96)	0.85 (0.64-0.98)	0.92 (0.82-1)	0.95 (0.88-1)
0.5	0 (0-0)	0 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.08)	0.15 (0-0.38)	0.38 (0.04-0.74)	0.6 (0.18-0.9)	0.73 (0.34-0.96)	0.86 (0.64-0.98)	0.91 (0.8-1)
0.55	0 (0-0)	0 (0-0)	0 (0-0.02)	0.01 (0-0.04)	0.05 (0-0.14)	0.19 (0-0.48)	0.37 (0.02-0.74)	0.52 (0.1-0.88)	0.72 (0.34-0.96)	0.82 (0.56-0.98)
0.6	0 (0-0)	0 (0-0)	0 (0-0.02)	0.01 (0-0.02)	0.02 (0-0.06)	0.05 (0-0.16)	0.15 (0-0.42)	0.27 (0-0.64)	0.49 (0.08-0.86)	0.63 (0.22-0.92)
0.65	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.02)	0.01 (0-0.02)	0.02 (0-0.04)	0.04 (0-0.12)	0.08 (0-0.24)	0.22 (0-0.56)	0.35 (0.02-0.72)
0.7	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.06)	0.06 (0-0.18)	0.12 (0-0.36)

Table B1.2. S-R Model: Ricker-PriorCap; Conservation Objective: ConObj1.5. Note this is a subset of the full tables that appear in the Research Document.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0.27 (0-0.86)	0.36 (0-0.88)	0.48 (0-0.9)	0.58 (0.06-0.94)	0.7 (0.2-0.98)	0.75 (0.24-0.98)	0.77 (0.24-1)	0.78 (0.22-1)	0.79 (0.22-1)	0.79 (0.2-1)
0.05	0.22 (0-0.78)	0.28 (0-0.8)	0.38 (0-0.86)	0.48 (0-0.9)	0.62 (0.06-0.96)	0.68 (0.1-0.98)	0.71 (0.08-1)	0.73 (0.12-1)	0.75 (0.1-1)	0.76 (0.08-1)
0.1	0.17 (0-0.66)	0.21 (0-0.68)	0.28 (0-0.74)	0.37 (0-0.82)	0.52 (0-0.92)	0.6 (0.02-0.96)	0.64 (0.04-0.98)	0.67 (0.04-1)	0.7 (0.04-1)	0.71 (0.02-1)
0.15	0.13 (0-0.52)	0.15 (0-0.52)	0.19 (0-0.58)	0.26 (0-0.66)	0.4 (0-0.84)	0.5 (0-0.92)	0.56 (0-0.96)	0.6 (0-0.98)	0.64 (0-1)	0.66 (0-1)
0.2	0.09 (0-0.38)	0.1 (0-0.34)	0.12 (0-0.4)	0.17 (0-0.48)	0.28 (0-0.7)	0.39 (0-0.86)	0.47 (0-0.92)	0.52 (0-0.96)	0.57 (0-0.98)	0.6 (0-1)
0.25	0.06 (0-0.22)	0.06 (0-0.22)	0.07 (0-0.26)	0.1 (0-0.3)	0.17 (0-0.5)	0.27 (0-0.72)	0.36 (0-0.84)	0.42 (0-0.92)	0.5 (0-0.98)	0.54 (0-0.98)
0.3	0.03 (0-0.08)	0.03 (0-0.1)	0.04 (0-0.14)	0.05 (0-0.16)	0.1 (0-0.3)	0.16 (0-0.5)	0.25 (0-0.68)	0.31 (0-0.82)	0.41 (0-0.94)	0.47 (0-0.96)
0.35	0.02 (0-0.04)	0.02 (0-0.06)	0.02 (0-0.06)	0.03 (0-0.08)	0.05 (0-0.16)	0.08 (0-0.28)	0.14 (0-0.48)	0.2 (0-0.66)	0.3 (0-0.86)	0.37 (0-0.94)
0.4	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.08)	0.04 (0-0.14)	0.06 (0-0.22)	0.11 (0-0.38)	0.19 (0-0.64)	0.27 (0-0.84)
0.45	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.06)	0.03 (0-0.1)	0.04 (0-0.16)	0.1 (0-0.36)	0.16 (0-0.6)
0.5	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.06)	0.04 (0-0.14)	0.07 (0-0.26)
0.55	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.06)	0.03 (0-0.1)
0.6	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)
0.65	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
0.7	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)

Table B1.3. S-R Model: Ricker-Dep; Conservation Objective: ConObj1.5. Note this is a subset of the full tables that appear in the Research Document.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0.05 (0-0.14)	0.09 (0-0.3)	0.12 (0-0.46)	0.16 (0-0.6)	0.23 (0-0.74)	0.3 (0-0.86)	0.35 (0-0.92)	0.4 (0-0.94)	0.47 (0-0.98)	0.52 (0-0.98)
0.05	0.03 (0-0.1)	0.06 (0-0.18)	0.08 (0-0.28)	0.1 (0-0.38)	0.16 (0-0.58)	0.22 (0-0.74)	0.27 (0-0.84)	0.31 (0-0.9)	0.38 (0-0.94)	0.43 (0-0.96)
0.1	0.02 (0-0.06)	0.03 (0-0.12)	0.05 (0-0.16)	0.07 (0-0.24)	0.1 (0-0.34)	0.15 (0-0.5)	0.19 (0-0.7)	0.23 (0-0.8)	0.3 (0-0.9)	0.35 (0-0.94)
0.15	0.01 (0-0.04)	0.02 (0-0.06)	0.03 (0-0.1)	0.04 (0-0.14)	0.06 (0-0.2)	0.09 (0-0.28)	0.12 (0-0.4)	0.16 (0-0.62)	0.22 (0-0.82)	0.26 (0-0.88)
0.2	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.06)	0.02 (0-0.08)	0.04 (0-0.14)	0.06 (0-0.18)	0.08 (0-0.26)	0.1 (0-0.34)	0.15 (0-0.62)	0.19 (0-0.76)
0.25	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.08)	0.04 (0-0.12)	0.04 (0-0.14)	0.05 (0-0.16)	0.09 (0-0.32)	0.13 (0-0.5)
0.3	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.06)	0.03 (0-0.08)	0.03 (0-0.12)	0.05 (0-0.16)	0.08 (0-0.26)
0.35	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.06)	0.03 (0-0.08)	0.04 (0-0.12)
0.4	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.02 (0-0.04)	0.02 (0-0.06)
0.45	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)
0.5	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)
0.55	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
0.6	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
0.65	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
0.7	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)

Table B2.1. S-R Model: base Ricker; Conservation Objective: MU>20k. Note this is a subset of the full tables that appear in the Research Document.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0.06 (0-0.14)	0.36 (0.06-0.74)	0.76 (0.52-0.94)	0.93 (0.84-1)	0.99 (0.96-1)	1 (0.98-1)	1 (1-1)	1 (1-1)	1 (1-1)	1 (1-1)
0.05	0.05 (0-0.1)	0.28 (0.04-0.64)	0.68 (0.38-0.9)	0.89 (0.76-1)	0.98 (0.94-1)	0.99 (0.98-1)	1 (1-1)	1 (1-1)	1 (1-1)	1 (1-1)
0.1	0.04 (0-0.08)	0.2 (0.02-0.5)	0.57 (0.26-0.84)	0.84 (0.66-0.98)	0.97 (0.92-1)	0.99 (0.98-1)	1 (0.98-1)	1 (1-1)	1 (1-1)	1 (1-1)
0.15	0.03 (0-0.04)	0.14 (0.02-0.36)	0.45 (0.14-0.74)	0.75 (0.54-0.92)	0.96 (0.88-1)	0.99 (0.96-1)	0.99 (0.98-1)	1 (0.98-1)	1 (1-1)	1 (1-1)
0.2	0.02 (0-0.04)	0.09 (0-0.24)	0.32 (0.06-0.62)	0.64 (0.38-0.86)	0.92 (0.82-1)	0.98 (0.92-1)	0.99 (0.96-1)	0.99 (0.98-1)	1 (1-1)	1 (1-1)
0.25	0.02 (0-0.04)	0.06 (0-0.14)	0.22 (0.04-0.48)	0.5 (0.2-0.78)	0.86 (0.7-0.98)	0.96 (0.88-1)	0.98 (0.94-1)	0.99 (0.98-1)	1 (0.98-1)	1 (1-1)
0.3	0.01 (0-0.04)	0.04 (0-0.08)	0.13 (0.02-0.32)	0.35 (0.08-0.62)	0.77 (0.54-0.94)	0.92 (0.8-1)	0.97 (0.9-1)	0.98 (0.94-1)	0.99 (0.98-1)	1 (1-1)
0.35	0.01 (0-0.04)	0.03 (0-0.06)	0.08 (0-0.18)	0.22 (0.04-0.46)	0.63 (0.34-0.88)	0.86 (0.68-1)	0.94 (0.82-1)	0.97 (0.9-1)	0.99 (0.96-1)	0.99 (0.98-1)
0.4	0.01 (0-0.02)	0.02 (0-0.04)	0.05 (0-0.1)	0.12 (0.02-0.28)	0.46 (0.16-0.76)	0.74 (0.46-0.96)	0.88 (0.68-1)	0.93 (0.82-1)	0.97 (0.92-1)	0.99 (0.96-1)
0.45	0.01 (0-0.02)	0.01 (0-0.04)	0.03 (0-0.06)	0.06 (0-0.14)	0.28 (0.04-0.56)	0.58 (0.24-0.86)	0.77 (0.5-0.98)	0.87 (0.66-1)	0.95 (0.86-1)	0.97 (0.92-1)
0.5	0 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.04)	0.04 (0-0.08)	0.14 (0.02-0.32)	0.37 (0.08-0.68)	0.6 (0.24-0.9)	0.75 (0.44-0.98)	0.89 (0.68-1)	0.94 (0.82-1)
0.55	0 (0-0.02)	0.01 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.04)	0.06 (0-0.14)	0.19 (0.04-0.4)	0.38 (0.08-0.72)	0.56 (0.16-0.9)	0.77 (0.44-1)	0.87 (0.64-1)
0.6	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.04)	0.03 (0-0.06)	0.08 (0-0.18)	0.19 (0.02-0.46)	0.32 (0.04-0.7)	0.57 (0.14-0.94)	0.73 (0.32-1)
0.65	0 (0-0)	0 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.04)	0.04 (0-0.08)	0.07 (0-0.18)	0.14 (0.02-0.34)	0.32 (0.04-0.72)	0.5 (0.1-0.92)
0.7	0 (0-0)	0 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.04)	0.03 (0-0.06)	0.04 (0-0.08)	0.06 (0-0.12)	0.15 (0.02-0.36)	0.26 (0.02-0.64)

Table B2.2. S-R Model: Ricker-PriorCap; Conservation Objective: MU>20k. Note this is a subset of the full tables that appear in the Research Document.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0.4 (0.02-0.98)	0.54 (0.08-0.98)	0.7 (0.36-0.98)	0.81 (0.58-1)	0.89 (0.7-1)	0.91 (0.72-1)	0.92 (0.74-1)	0.92 (0.74-1)	0.92 (0.7-1)	0.92 (0.7-1)
0.05	0.35 (0-0.94)	0.46 (0.04-0.92)	0.59 (0.22-0.94)	0.71 (0.42-0.96)	0.83 (0.58-1)	0.87 (0.62-1)	0.88 (0.62-1)	0.89 (0.62-1)	0.89 (0.6-1)	0.89 (0.58-1)
0.1	0.3 (0-0.88)	0.37 (0.04-0.84)	0.48 (0.1-0.88)	0.59 (0.26-0.92)	0.74 (0.42-0.98)	0.8 (0.48-1)	0.83 (0.48-1)	0.84 (0.5-1)	0.85 (0.44-1)	0.85 (0.44-1)
0.15	0.24 (0-0.8)	0.29 (0.02-0.74)	0.36 (0.04-0.74)	0.45 (0.14-0.8)	0.62 (0.28-0.94)	0.71 (0.34-1)	0.75 (0.34-1)	0.78 (0.32-1)	0.8 (0.32-1)	0.81 (0.3-1)
0.2	0.19 (0-0.68)	0.22 (0.02-0.62)	0.26 (0.04-0.58)	0.32 (0.06-0.62)	0.48 (0.16-0.82)	0.6 (0.2-0.96)	0.66 (0.22-1)	0.69 (0.2-1)	0.73 (0.2-1)	0.75 (0.18-1)
0.25	0.15 (0-0.52)	0.16 (0-0.46)	0.18 (0.02-0.44)	0.22 (0.04-0.48)	0.33 (0.06-0.68)	0.46 (0.12-0.86)	0.54 (0.12-0.96)	0.59 (0.12-0.98)	0.65 (0.1-1)	0.68 (0.1-1)
0.3	0.1 (0-0.34)	0.11 (0-0.3)	0.12 (0-0.28)	0.14 (0.02-0.32)	0.21 (0.04-0.48)	0.31 (0.04-0.68)	0.41 (0.06-0.86)	0.48 (0.06-0.94)	0.56 (0.06-1)	0.6 (0.06-1)
0.35	0.07 (0-0.2)	0.07 (0-0.18)	0.08 (0-0.18)	0.09 (0-0.2)	0.13 (0.02-0.28)	0.19 (0.02-0.48)	0.27 (0.02-0.64)	0.35 (0.04-0.8)	0.45 (0.02-0.96)	0.51 (0.04-1)
0.4	0.05 (0-0.12)	0.05 (0-0.1)	0.05 (0-0.1)	0.06 (0-0.12)	0.08 (0-0.16)	0.11 (0-0.24)	0.16 (0.02-0.4)	0.21 (0.02-0.56)	0.32 (0.02-0.84)	0.4 (0.02-0.94)
0.45	0.04 (0-0.06)	0.03 (0-0.06)	0.04 (0-0.06)	0.04 (0-0.08)	0.05 (0-0.1)	0.07 (0-0.14)	0.09 (0-0.2)	0.12 (0-0.3)	0.2 (0-0.56)	0.27 (0.02-0.78)
0.5	0.02 (0-0.04)	0.03 (0-0.04)	0.03 (0-0.04)	0.03 (0-0.06)	0.03 (0-0.06)	0.04 (0-0.08)	0.05 (0-0.12)	0.07 (0-0.16)	0.11 (0-0.28)	0.16 (0-0.46)
0.55	0.01 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.03 (0-0.04)	0.03 (0-0.06)	0.03 (0-0.06)	0.04 (0-0.08)	0.06 (0-0.12)	0.08 (0-0.2)
0.6	0.01 (0-0.04)	0.01 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.03 (0-0.06)	0.04 (0-0.1)
0.65	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.02 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.03 (0-0.06)
0.7	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)

Table B2.3. S-R Model: Ricker-Dep; Conservation Objective: MU>20k. Note this is a subset of the full tables that appear in the Research Document. The yellow highlighted cells refer to Example B in Appendix A3. The green highlighted cell refers to Example C in Appendix A3.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0.35 (0.04-0.82)	0.51 (0.1-0.92)	0.63 (0.24-0.96)	0.72 (0.38-0.98)	0.82 (0.52-1)	0.86 (0.62-1)	0.89 (0.64-1)	0.9 (0.68-1)	0.91 (0.7-1)	0.92 (0.74-1)
0.05	0.27 (0.02-0.68)	0.4 (0.06-0.82)	0.51 (0.12-0.88)	0.61 (0.2-0.94)	0.73 (0.36-0.98)	**0.79 (0.44-1)**	0.83 (0.5-1)	0.85 (0.54-1)	0.87 (0.62-1)	0.89 (0.62-1)
0.1	0.2 (0.02-0.52)	0.29 (0.04-0.7)	0.39 (0.06-0.78)	**0.48 (0.12-0.86)**	0.61 (0.18-0.94)	**0.69 (0.26-0.98)**	0.74 (0.32-1)	0.77 (0.38-1)	0.81 (0.42-1)	0.83 (0.48-1)
0.15	0.14 (0-0.38)	0.2 (0.02-0.5)	0.27 (0.04-0.62)	0.34 (0.06-0.72)	0.47 (0.1-0.86)	0.57 (0.14-0.94)	0.63 (0.18-0.98)	0.67 (0.2-1)	0.72 (0.22-1)	0.75 (0.26-1)
0.2	0.1 (0-0.24)	0.14 (0.02-0.34)	0.18 (0.02-0.42)	0.23 (0.02-0.52)	0.33 (0.04-0.72)	0.43 (0.08-0.84)	0.5 (0.1-0.92)	0.55 (0.1-0.96)	0.62 (0.14-1)	0.66 (0.16-1)
0.25	0.07 (0-0.16)	0.09 (0-0.22)	0.12 (0.02-0.28)	0.15 (0.02-0.36)	0.22 (0.02-0.52)	0.29 (0.04-0.68)	0.36 (0.04-0.8)	0.42 (0.06-0.9)	0.5 (0.06-0.96)	0.55 (0.06-1)
0.3	0.05 (0-0.12)	0.06 (0-0.16)	0.08 (0-0.2)	0.1 (0-0.22)	0.14 (0.02-0.32)	0.19 (0.02-0.48)	0.24 (0.02-0.6)	0.29 (0.02-0.72)	0.37 (0.04-0.9)	0.43 (0.04-0.96)
0.35	0.03 (0-0.08)	0.05 (0-0.1)	0.05 (0-0.12)	0.07 (0-0.16)	0.09 (0-0.2)	0.12 (0.02-0.26)	0.15 (0.02-0.36)	0.18 (0.02-0.5)	0.25 (0.02-0.7)	0.31 (0.02-0.82)
0.4	0.03 (0-0.06)	0.03 (0-0.08)	0.04 (0-0.1)	0.05 (0-0.12)	0.06 (0-0.14)	0.08 (0-0.16)	0.09 (0-0.22)	0.11 (0-0.26)	0.16 (0-0.44)	0.2 (0.02-0.6)
0.45	0.02 (0-0.04)	0.03 (0-0.06)	0.03 (0-0.08)	0.03 (0-0.08)	0.04 (0-0.1)	0.05 (0-0.12)	0.06 (0-0.12)	0.07 (0-0.16)	0.1 (0-0.24)	0.13 (0-0.32)
0.5	0.01 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.03 (0-0.06)	0.03 (0-0.08)	0.03 (0-0.08)	0.04 (0-0.1)	0.05 (0-0.1)	0.06 (0-0.14)	0.07 (0-0.16)
0.55	0.01 (0-0.02)	0.01 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.06)	0.03 (0-0.06)	0.03 (0-0.08)	0.04 (0-0.1)	0.04 (0-0.1)
0.6	0.01 (0-0.02)	0.01 (0-0.04)	0.01 (0-0.04)	0.01 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.04)	0.02 (0-0.06)	0.03 (0-0.06)
0.65	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.01 (0-0.04)	0.01 (0-0.04)	0.01 (0-0.04)	0.02 (0-0.04)
0.7	0 (0-0.02)	0 (0-0.02)	0 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.02)	0.01 (0-0.04)	0.01 (0-0.04)

Table B3.1. S-R Model: base Ricker; Conservation Objective: MU>40k. Note this is a subset of the full tables that appear in the Research Document.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0 (0-0)	0.01 (0-0.02)	0.05 (0-0.14)	0.17 (0.06-0.3)	0.46 (0.26-0.66)	0.64 (0.44-0.84)	0.74 (0.56-0.92)	0.8 (0.64-0.96)	0.87 (0.72-0.98)	0.9 (0.8-0.98)
0.05	0 (0-0)	0 (0-0.02)	0.03 (0-0.08)	0.12 (0.02-0.24)	0.39 (0.22-0.6)	0.58 (0.36-0.8)	0.7 (0.5-0.9)	0.77 (0.58-0.94)	0.85 (0.68-0.98)	0.88 (0.76-0.98)
0.1	0 (0-0)	0 (0-0)	0.02 (0-0.06)	0.08 (0-0.16)	0.31 (0.14-0.52)	0.51 (0.3-0.74)	0.65 (0.42-0.86)	0.73 (0.52-0.92)	0.82 (0.64-0.96)	0.86 (0.7-0.98)
0.15	0 (0-0)	0 (0-0)	0.01 (0-0.04)	0.04 (0-0.1)	0.23 (0.08-0.4)	0.44 (0.22-0.68)	0.58 (0.34-0.82)	0.68 (0.44-0.9)	0.78 (0.58-0.96)	0.84 (0.66-0.98)
0.2	0 (0-0)	0 (0-0)	0 (0-0.02)	0.02 (0-0.06)	0.16 (0.04-0.3)	0.36 (0.16-0.6)	0.51 (0.26-0.76)	0.62 (0.36-0.86)	0.74 (0.52-0.94)	0.81 (0.62-0.96)
0.25	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.04)	0.1 (0-0.22)	0.27 (0.08-0.5)	0.42 (0.18-0.7)	0.54 (0.26-0.8)	0.69 (0.42-0.92)	0.77 (0.56-0.96)
0.3	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.02)	0.05 (0-0.12)	0.18 (0.04-0.36)	0.33 (0.1-0.6)	0.45 (0.18-0.74)	0.62 (0.32-0.88)	0.72 (0.44-0.94)
0.35	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.02 (0-0.06)	0.11 (0-0.24)	0.23 (0.06-0.46)	0.36 (0.12-0.64)	0.54 (0.22-0.84)	0.65 (0.36-0.92)
0.4	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.04)	0.06 (0-0.14)	0.15 (0-0.32)	0.25 (0.04-0.5)	0.44 (0.14-0.78)	0.57 (0.24-0.88)
0.45	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.02 (0-0.06)	0.08 (0-0.2)	0.16 (0-0.34)	0.33 (0.06-0.64)	0.47 (0.14-0.8)
0.5	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.03 (0-0.1)	0.08 (0-0.22)	0.21 (0.02-0.5)	0.35 (0.06-0.68)
0.55	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.04)	0.03 (0-0.1)	0.12 (0-0.3)	0.22 (0-0.52)
0.6	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.04)	0.05 (0-0.14)	0.12 (0-0.34)
0.65	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.02 (0-0.06)	0.05 (0-0.14)
0.7	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.04)	0.02 (0-0.06)

Table B3.2. S-R Model: Ricker –PriorCap; Conservation Objective: MU>40k. Note this is a subset of the full tables that appear in the Research Document.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0.12 (0-0.4)	0.13 (0-0.4)	0.16 (0-0.42)	0.21 (0-0.5)	0.33 (0.06-0.66)	0.42 (0.08-0.8)	0.48 (0.08-0.86)	0.53 (0.08-0.9)	0.58 (0.08-0.94)	0.61 (0.08-0.96)
0.05	0.1 (0-0.32)	0.1 (0-0.3)	0.12 (0-0.32)	0.15 (0-0.38)	0.24 (0.02-0.54)	0.34 (0.04-0.72)	0.4 (0.04-0.8)	0.45 (0.04-0.84)	0.51 (0.04-0.9)	0.55 (0.04-0.94)
0.1	0.07 (0-0.22)	0.07 (0-0.2)	0.08 (0-0.2)	0.1 (0-0.24)	0.17 (0-0.4)	0.25 (0-0.6)	0.32 (0.02-0.74)	0.37 (0.02-0.8)	0.45 (0.02-0.88)	0.49 (0.02-0.92)
0.15	0.05 (0-0.14)	0.05 (0-0.12)	0.06 (0-0.12)	0.07 (0-0.14)	0.11 (0-0.28)	0.17 (0-0.46)	0.24 (0-0.62)	0.3 (0-0.74)	0.38 (0-0.84)	0.43 (0-0.88)
0.2	0.04 (0-0.06)	0.04 (0-0.06)	0.04 (0-0.06)	0.04 (0-0.08)	0.07 (0-0.16)	0.11 (0-0.3)	0.16 (0-0.46)	0.21 (0-0.62)	0.3 (0-0.76)	0.36 (0-0.84)
0.25	0.03 (0-0.02)	0.03 (0-0.02)	0.03 (0-0.02)	0.03 (0-0.04)	0.04 (0-0.08)	0.06 (0-0.14)	0.1 (0-0.3)	0.14 (0-0.44)	0.22 (0-0.66)	0.29 (0-0.78)
0.3	0.02 (0-0)	0.02 (0-0)	0.02 (0-0)	0.02 (0-0)	0.03 (0-0.04)	0.04 (0-0.06)	0.06 (0-0.16)	0.09 (0-0.26)	0.15 (0-0.52)	0.21 (0-0.7)
0.35	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.02 (0-0)	0.02 (0-0)	0.02 (0-0.02)	0.03 (0-0.04)	0.05 (0-0.12)	0.09 (0-0.28)	0.14 (0-0.46)
0.4	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.02 (0-0.02)	0.02 (0-0.02)	0.04 (0-0.12)	0.08 (0-0.24)
0.45	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.02 (0-0.02)	0.04 (0-0.1)
0.5	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)	0.02 (0-0.02)
0.55	0 (0-0)	0.01 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)	0.01 (0-0)	0.01 (0-0)
0.6	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)
0.65	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)
0.7	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)	0 (0-0)

Table B3.3. S-R Model: Ricker-Dep; Conservation Objective: MU>40k. Note this is a subset of the full tables that appear in the Research Document.

Exploitation Rate	Hatchery Smolt-to-Adult Survival Rate									
	0.0025	**0.005**	**0.0075**	**0.01**	**0.015**	**0.02**	**0.025**	**0.03**	**0.04**	**0.05**
0	0.05 (0-0.16)	0.09 (0-0.26)	0.13 (0-0.34)	0.18 (0-0.44)	0.28 (0.04-0.58)	0.35 (0.06-0.7)	0.4 (0.08-0.76)	0.44 (0.1-0.8)	0.5 (0.12-0.88)	0.54 (0.14-0.92)
0.05	0.03 (0-0.1)	0.06 (0-0.18)	0.08 (0-0.22)	0.12 (0-0.32)	0.19 (0-0.48)	0.26 (0.02-0.58)	0.32 (0.02-0.68)	0.36 (0.04-0.74)	0.42 (0.06-0.82)	0.47 (0.06-0.88)
0.1	0.02 (0-0.06)	0.03 (0-0.1)	0.05 (0-0.14)	0.07 (0-0.2)	0.13 (0-0.36)	0.18 (0-0.46)	0.23 (0-0.58)	0.28 (0-0.66)	0.34 (0.02-0.76)	0.39 (0.02-0.84)
0.15	0.01 (0-0.02)	0.02 (0-0.06)	0.03 (0-0.08)	0.04 (0-0.12)	0.08 (0-0.2)	0.12 (0-0.32)	0.16 (0-0.44)	0.2 (0-0.52)	0.26 (0-0.68)	0.31 (0-0.76)
0.2	0.01 (0-0)	0.01 (0-0.02)	0.01 (0-0.04)	0.02 (0-0.06)	0.04 (0-0.1)	0.07 (0-0.2)	0.1 (0-0.28)	0.13 (0-0.38)	0.19 (0-0.52)	0.23 (0-0.66)
0.25	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)	0.02 (0-0.04)	0.03 (0-0.1)	0.05 (0-0.16)	0.07 (0-0.24)	0.12 (0-0.4)	0.16 (0-0.52)
0.3	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.02 (0-0.04)	0.03 (0-0.06)	0.04 (0-0.12)	0.07 (0-0.24)	0.1 (0-0.36)
0.35	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0.02)	0.01 (0-0.02)	0.02 (0-0.04)	0.04 (0-0.1)	0.06 (0-0.18)
0.4	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)	0.01 (0-0)	0.02 (0-0.04)	0.03 (0-0.06)
0.45	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)	0.01 (0-0.02)
0.5	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.01 (0-0)
0.55	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
0.6	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
0.65	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
0.7	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)

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