Update on the development of the 2020 stock assessment

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PURPOSE

To provide the IPHC's Scientific Review Board (SRB) with a response to requests made during SRB016 (IPHC-2020-SRB016-R) and to provide the Commission with an update on the development of the 2020 stock assessment.

INTRODUCTION

The 2019 stock assessment included a complete re-evaluation of all data sources and modelling choices as part of a full stock assessment analysis. A summary of results (IPHC-2020-AM096-09 Rev_2) was presented to the Commission during AM095 (Stewart et al. 2020b). Full assessment (Stewart and Hicks 2020) and data overview (Stewart and Webster 2020) documents were posted directly to the stock assessment page of the IPHC's website. The 2019 scientific review comprised both the standard SRB reviews in June (SRB014) and September (SRB015), as well an external peer review (Stokes 2019).

This document builds upon the preliminary stock assessment development reported for SRB016 (IPHC-2020-SRB016-07). It includes updates on requests made during SRB016, and on additional development toward the final 2020 stock assessment. The 2020 assessment represents an update of the 2019 assessment, and will include two new sources of information: recreational fishery sex-ratio data and 2019 commercial fishery sex-ratio data, as well as newly available information from existing data series collected during 2020. The assessment model structure was updated for SRB016 in order to accommodate sex-specific selectivity for the recreational mortality; there are no additional structural changes to the individual models or the ensemble.

SRB REQUESTS AND RESULTS

The SRB made the following four requests during SRB016:

1. SRB016–Req.04 (para. 21): *"The SRB AGREED that data weighting approaches, including alternative error distributions (e.g. self-weighting), should be evaluated further in the context of the next full stock assessment, and should strive to make use of the best methods available, noting that there are a range of approaches in use for similar stock assessments. In particular, the SRB REQUESTED that the IPHC Secretariat investigate the feasibility of a logistic-normal distribution to incorporate correlated errors in age composition data (see Francis, R.I.C.C. 2014. Replacing the multinomial in stock assessment models: A first step. Fisheries Research 151: 70–84). This change may be technically challenging given the current assessment software, as well as having sexed age composition data, and could non-trivially affect the stock assessment estimates of biomass and recruitment. Therefore, the SRB does not expect new results until at least SRB018 in June 2021."*
2. SRB016 (para. 20): *"The SRB REQUESTED that the IPHC Secretariat continue to update data weighting on an annual basis, even for updated stock assessments, in order to maintain internal model consistency and to best reflect changes in existing and new data as they arise."*
3. SRB016 (para. 22): *"The SRB REQUESTED that the Secretariat staff continue to evaluate whether the Stock Synthesis modelling framework is the most efficient for*

Commission needs, and to coordinate future development with the MSE framework as features and technical needs evolve together for the two efforts."

4. SRB016 (para. 23): *"The SRB REQUESTED an update at SRB017 on all data available at that time and any additional changes anticipated for the final 2020 stock assessment."*

These four requests are addressed below. As for SRB016, all results are based on individual models extended to include 2020 (preliminarily including projected 2020 mortality from all sources based on the mortality limits set during AM096). Software was updated to use stock synthesis version 3.30.15.09, from the version used for the 2019 stock assessment (3.30.13) and for SRB016 (3.30.14). Most of the changes to the software were unimportant for the assessment of Pacific halibut; however, on request from the Secretariat staff NOAA Fisheries developers added the calculation and reporting of variance estimates for the dynamic unfished spawning biomass. This quantity is used to calculate the relative biomass in each year for use in the IPHC's interim management procedure, and the variance (and covariance) calculations replace a proxy variance and covariance used for the 2019 stock assessment (Stewart and Hicks 2019). Effects of this change are described as part of the fourth request below.

Request 1 – logistic-normal for composition data

After investigating the Dirichlet-multinomial for SRB016, the Secretariat staff identified four issues that made its use non-optimal for the Pacific halibut stock assessment (and likely many other assessments). These issues were:

1) Increased weighting of small samples as the estimated variance in the composition data gets large.

2) The parameterization is not self-weighting near the nominal sample size as the estimated parameter goes to a bound and requires fixing at a static value to avoid potential estimation problems.

3) The approach produced standardized residuals that were inconsistent with the likelihood assumption (far more than 2.5% > 1.96).

4) The Dirichlet-multinomial does not allow for the correlation structure known to exist among proportions-at-age (or length).

On request from SRB016, the Secretariat staff reviewed the recent literature on error distributions for compositional data, with a particular focus on the logistic-normal. Francis (2014) introduces several likelihood function options for compositional data and provides discussion of each with relative shortcomings and advantages. He found clear theoretical support for the logistic-normal because: 1) it is self-weighting (not requiring an iterative approach), 2) his suggested parameterization can maintain the relative annual input sample sizes in the likelihood, and 3) it allows for estimated correlations among bins. He noted that the logistic-normal does not allow for zero proportions, and so requires compressing the tails of the distribution to positive values and/or a method for either combining bins with internal zeros or adding a small constant to observed (and expected) proportions. His analysis did not include fitting assessment models to data, but instead relied on comparing the likelihood of previous assessment model fits to compositional data. He found the LM performed well in most cases, but was quite sensitive to the choice of the small robustifying constant added to zero observations.

To address the variance and correlation structure among bins, he described three cases: 'LN1' with just a single variance parameter (σ), 'LN2' using an AR(1) process and including one additional correlation parameter, and 'LN3' using an AR(2) process and also adding a second correlation parameter. Francis suggested that the estimated variance parameter (σ) may be multiplied by some function of the input sample size (*n*) in each year (*y*) to retain the inter-annual variability created by the sampling intensity, as well as the variability inherent in the compositional data for each data set. This seemingly reasonable approach increases the weight as the sample size increases, but less so at very large sample sizes relative to the mean ($\bar{n}$):

$$\sigma_y = \sigma \left({}^{\bar{n}}/_{n_y} \right)^{0.5}$$

Francis suggested that allowing for a realistic correlation structure was one of the primary benefits of the logisitic-normal. He found that this correlation structure included both positive and negative correlations among age bins, and clearly did not following the structure implied by the simple multinomial. Miller and Skalski (2006) also found a complex correlation structures in fisheries length data that did not resemble that of a multinomial or Dirichlet-multinomial, with correlations among bins that were both positive and negative. The largest remaining impediment to application of the logistic-normal identified by Francis was the need to allow for a two-dimensional correlation structure that included both males and females for data that were sex-specific. Francis specifically notes that any simple AR(1) or AR(2) process would be incomplete, as the order of the bins among the two sexes would matter because the correlation structure operates on the bin index.

Other authors have both investigated and implemented versions of the logistic-normal. Cadigan (2016) used the multiplicative logistic-normal in a state-space model for Atlantic cod. His example was relatively simple compared to Pacific halibut: he had sexes-aggregated data, did not retain the annual sample sizes, and did not include correlations among the proportions, instead estimating a single variance parameter for all proportions that was then adjusted using *ad hoc* scaling of the youngest (age-2) and oldest (age-8+) bins. Schnute and Richards (1995) used what they called the 'multivariate logistic', which appears to be equivalent to the logistic-normal later described by Schnute and Haigh (2007). These authors also did not include sex-specific compositional data or include a provision to weight the variance by the observed sample size in each year. Finally, Albertsen et al. (2017) compared a range of compositional models (among other structuring choices, including comparing numbers-at-age with proportions-at-age), including the Dirichlet and logistic-normal, and finding that the latter performed better on their data sets. They considered both the additive and multiplicative versions of the logistic-normal. They used an AR(1) approach to correlation among age bins but again did not have sex-specific information.

Specifically for the halibut stock assessment there should be little problem with the robustifying constant for internal zeros (there are none in our current data sets) and the assessment already compresses the tails to the first positive observation. Due to the importance of sex-specific age composition data to the estimation of historical and current population dynamics, any proposed likelihood must be able to accommodate sex-specific data in a meaningful way. This means that we would need to explore methods for allowing a two-dimensional correlation among age- and sex-specific bins, where (for example) males and females of the same (or similar) age might be more correlated than those of differing ages, and within a sex similar ages are more correlated than those that are very different (Figure 1).

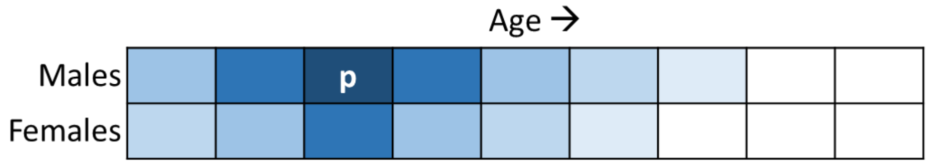

Figure 1. One type of hypothetical correlation (colors denote a negative or positive relationship with intensity equal to the correlation) between a specific male proportion-at-age (p) and surrounding ages for males and females. Note that evidence for this type of correlation was not found in all data sets by Francis (2014).

The Secretariat will continue to investigate published work for approaches to model two-dimensional correlation structure, and may initiate a graduate student project or other collaboration in order to potentially derive and test a candidate logistic-normal implementation that meets all of the needs of the current Pacific halibut stock assessment. A further update will be provided at SRB018.

Request 2 – update data weighting

The weighting of compositional data will be updated as one of the last steps in developing the final 2020 stock assessment, along with checking parameters on bounds and other convergence criteria, after all available data sources have been included.

Request 3 – modelling framework considerations

The only new information to report on this topic is the addition of the direct estimation of the variance of the unfished stock size in each year (‘dynamic SB_0’) of the modelled time-series to the optional outputs from stock synthesis. The IPHC Secretariat staff had contacted the SS development team with this need in 2019, and it was subsequently included in recent mid-version releases of 3.30.15 (in time for use in the 2020 stock assessment development). Although this process of requesting a new feature represented a delay in the implementation of the full calculation, the SS development team remains responsive and helpful to IPHC requests and the level of trouble-shooting required by IPHC Secretariat staff was modest.

Request 4 – data and model updates for 2020

Bridging and final steps for 2020 modelling

For SRB016 the 2019 stock assessment models were extended to 2021, and the newly available recreational sex-ratios-at-age included in the model fitting. To create a ‘bridge’ from the 2019 results to 2020, three steps were taken for SRB017:

1) Go back to the extended time-series and update to the newest version of stock synthesis available (3.30.15.09).
2) Add the recreational data again (and allow for separate selectivity asymptotes for males and females as done earlier).

3) Include the newly available sex-ratios-at-age for the 2019 commercial fishery (building on the 2017 and 2018 sex-ratios used in the 2019 stock assessment).

The first bridging step allowed for the directed estimation of the variance of the unfished spawning biomass in each year as well as the covariance of this quantity and the estimated spawning biomass in each year; the two quantities used to describe the relative stock status. In the 2019 stock assessment, the variance of the unfished spawning biomass in each year and the covariance with the estimated spawning biomass were both unavailable, so proxy values were used (Stewart et al. 2020a). These proxies proved to be quite close to the actual estimates, resulting in only a very small change to the estimated relative spawning biomass at the beginning of 2021 in the context of the approximate 95% asymptotic confidence intervals (Table 1). There was no change in the estimated spawning biomass or recruitment time-series for the short coastwide model (Figure 2), the long coastwide model (Figure 3), the short areas-as-fleets model (Figure 4) or the long areas-as-fleets model (Figure 5) as a function of the software version change.

Table 1. Comparison of relative biomass at the beginning of 2021 (prior to the addition of any new data other than the projected mortality for 2020) using the approximation from the 2019 stock assessment, and the improved calculation of variance available for the 2020 stock assessment. Low and high values correspond to an approximate 95% confidence interval.

	Low	$SB_{2021,fished}/SB_{2021,unfished}$	High	$P(SB_{2021}<SB_{30\%})$	$P(SB_{2021}<SB_{20\%})$
Approx. in 2019	20.1%	31.5%	46.2%	49	2
Calc. for 2020	19.8%	30.3%	47.4%	49	3

As observed previously, the recreational sex-ratio information had only a small effect on the time-series estimates. Similarly, the addition of the 2019 commercial sex-ratio estimates also had a very small effect on the stock assessment results. This is likely due to the aggregate fishery proportions observed for 2019 being very similar to those from 2017 and 2018 (Figure 6). Although the sample sizes (particularly for Biological Region 4B) are somewhat smaller when disaggregated to age-specific sex-ratios, the general pattern remained similar over the three years: a very high ratio of females at the younger ages (where males have a low probability of exceeding the minimum size limit) trending toward a more equal ratio at the oldest ages (Figure 7). There was a trend toward a lower percent female across the three years in all Biological Regions (Table 2). This may be due to the weak cohorts from 2006-2010 leading to an increase in the average age in the landings. Additional years of data will be needed to better delineate between real trends and inter-annual variability as they affect projection of fishing intensity when setting mortality limits for the upcoming year.

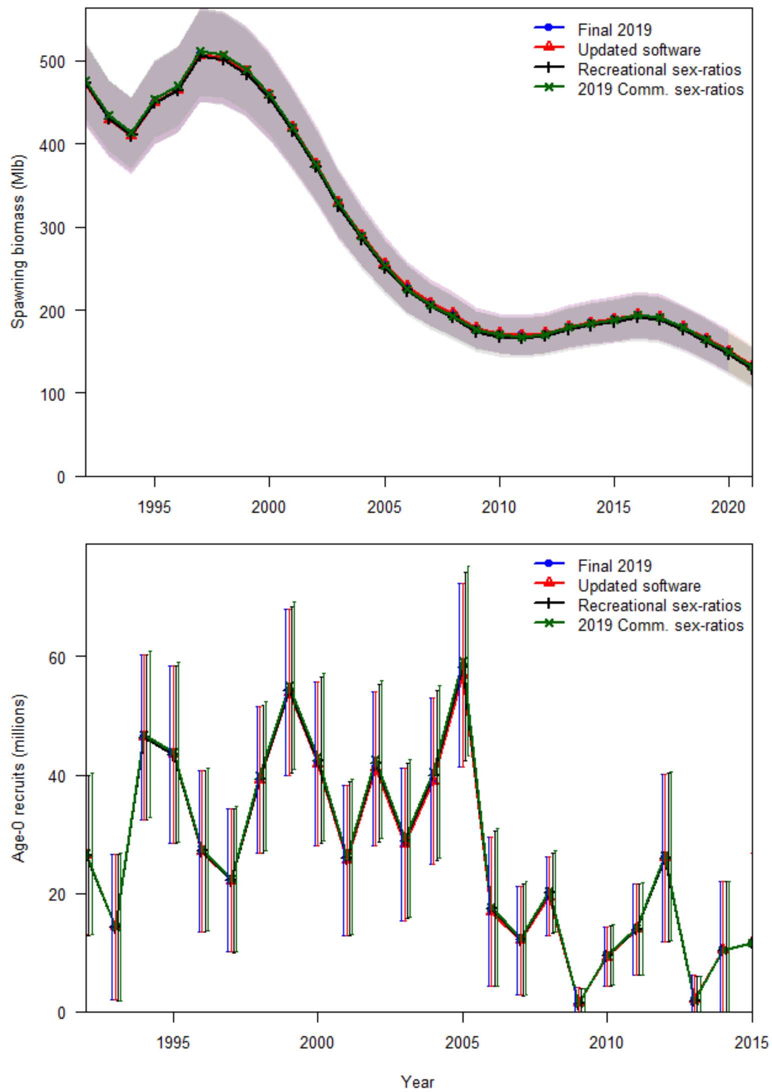

Figure 2. Bridging analysis for spawning biomass (upper panel) and recruitment (lower panel) for the short coastwide assessment model.

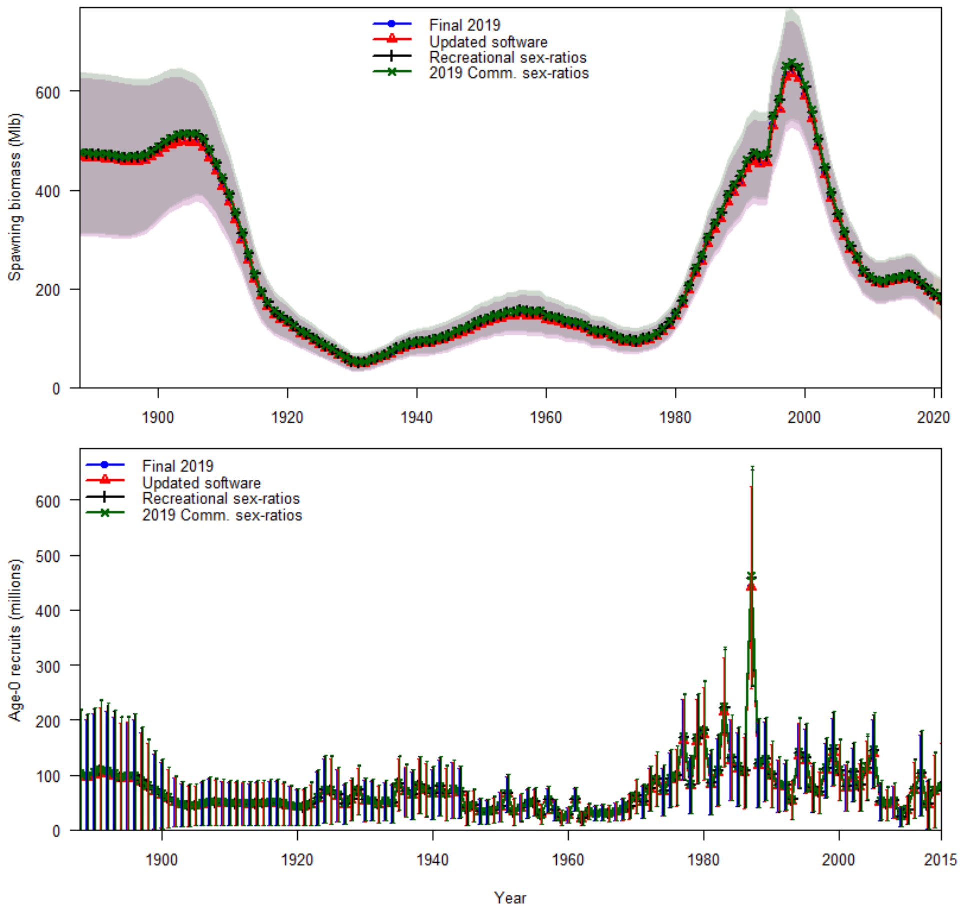

Figure 3. Bridging analysis for spawning biomass (upper panel) and recruitment (lower panel) for the long coastwide assessment model.

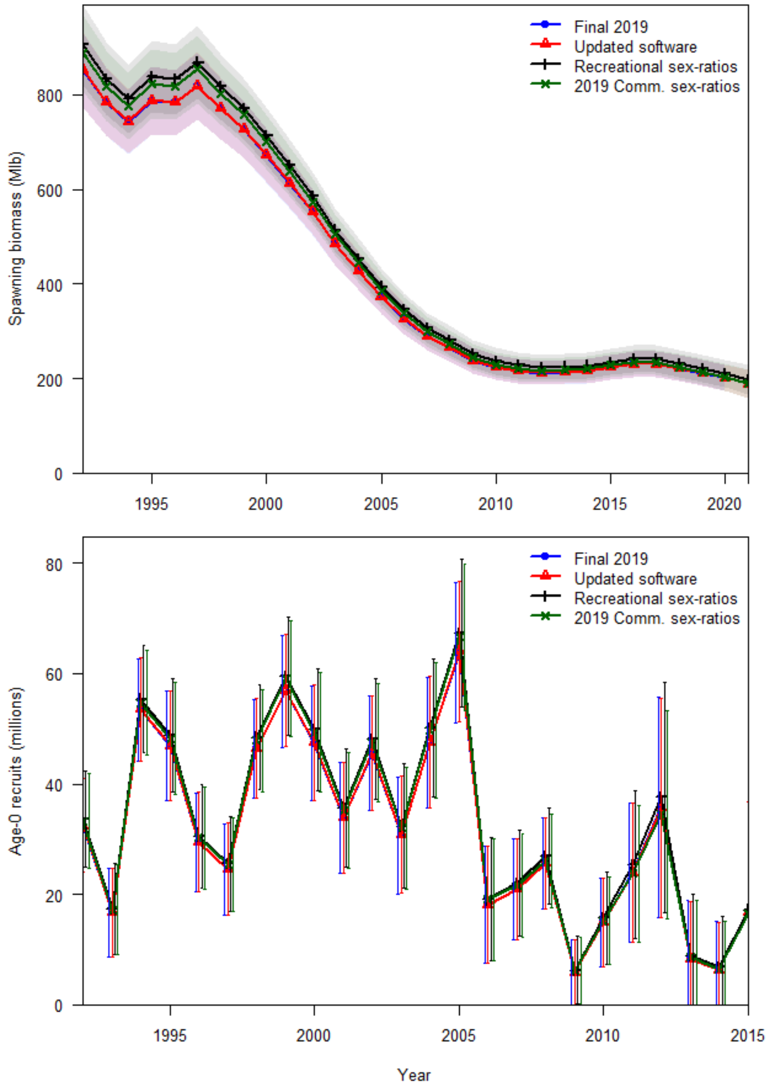

Figure 4. Bridging analysis for spawning biomass (upper panel) and recruitment (lower panel) for the short areas-as-fleets assessment model.

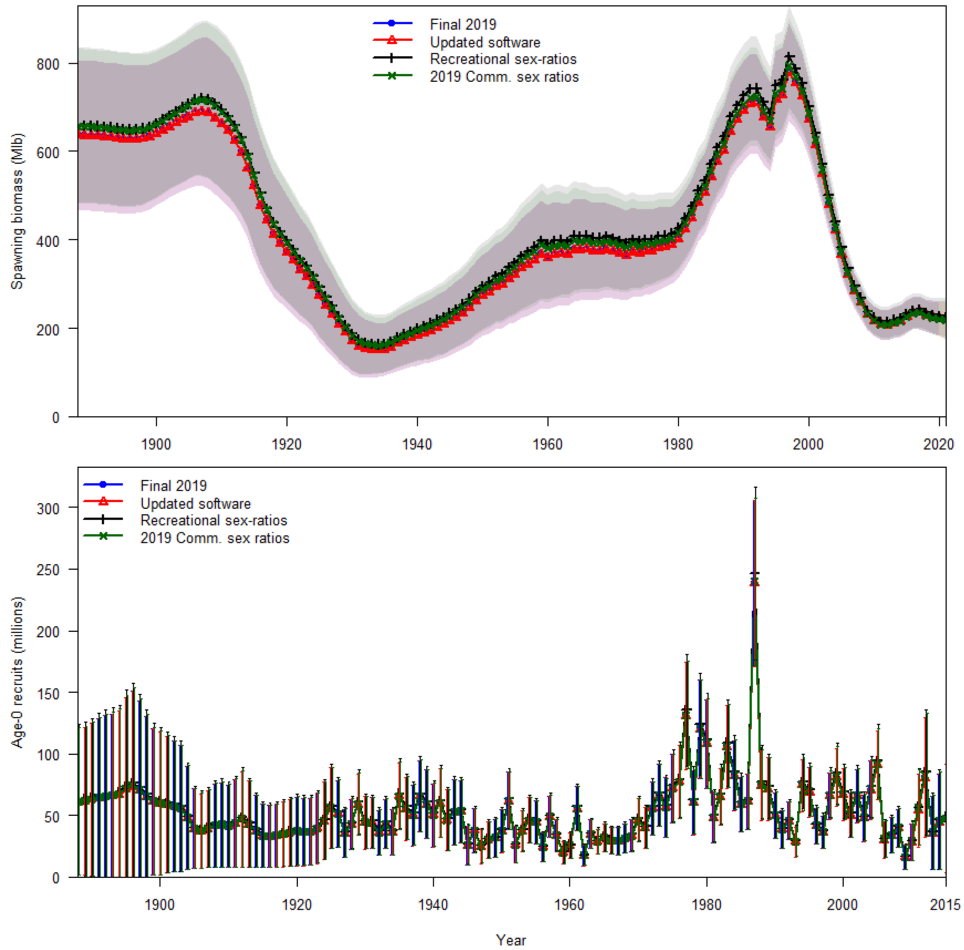

Figure 5. Bridging analysis for spawning biomass (upper panel) and recruitment (lower panel) for the long areas-as-fleets assessment model.

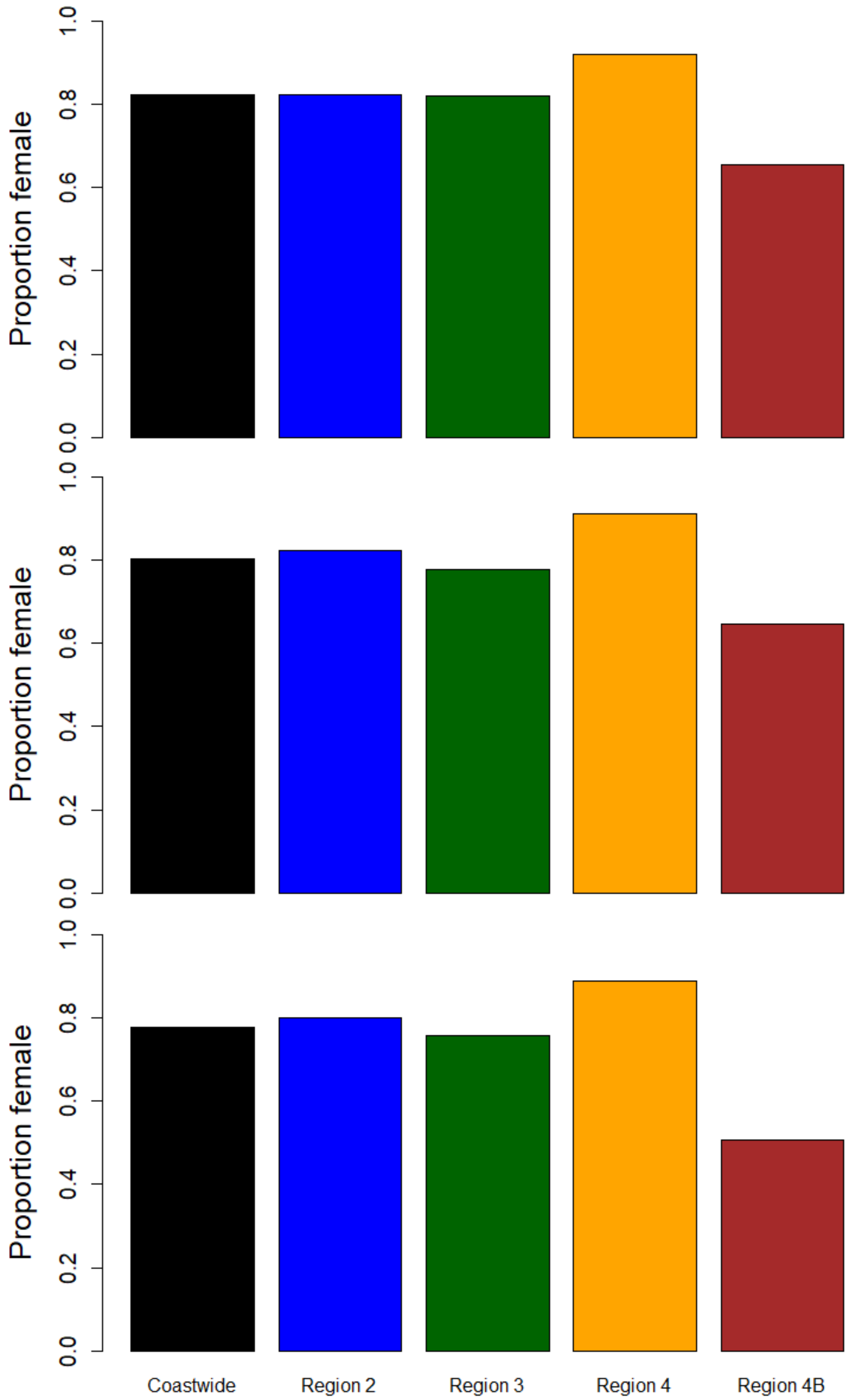

Figure 6. Commercial sex-ratios for 2017 (upper panel), 2018 (middle panel) and 2019 (lower panel) by Biological Region.

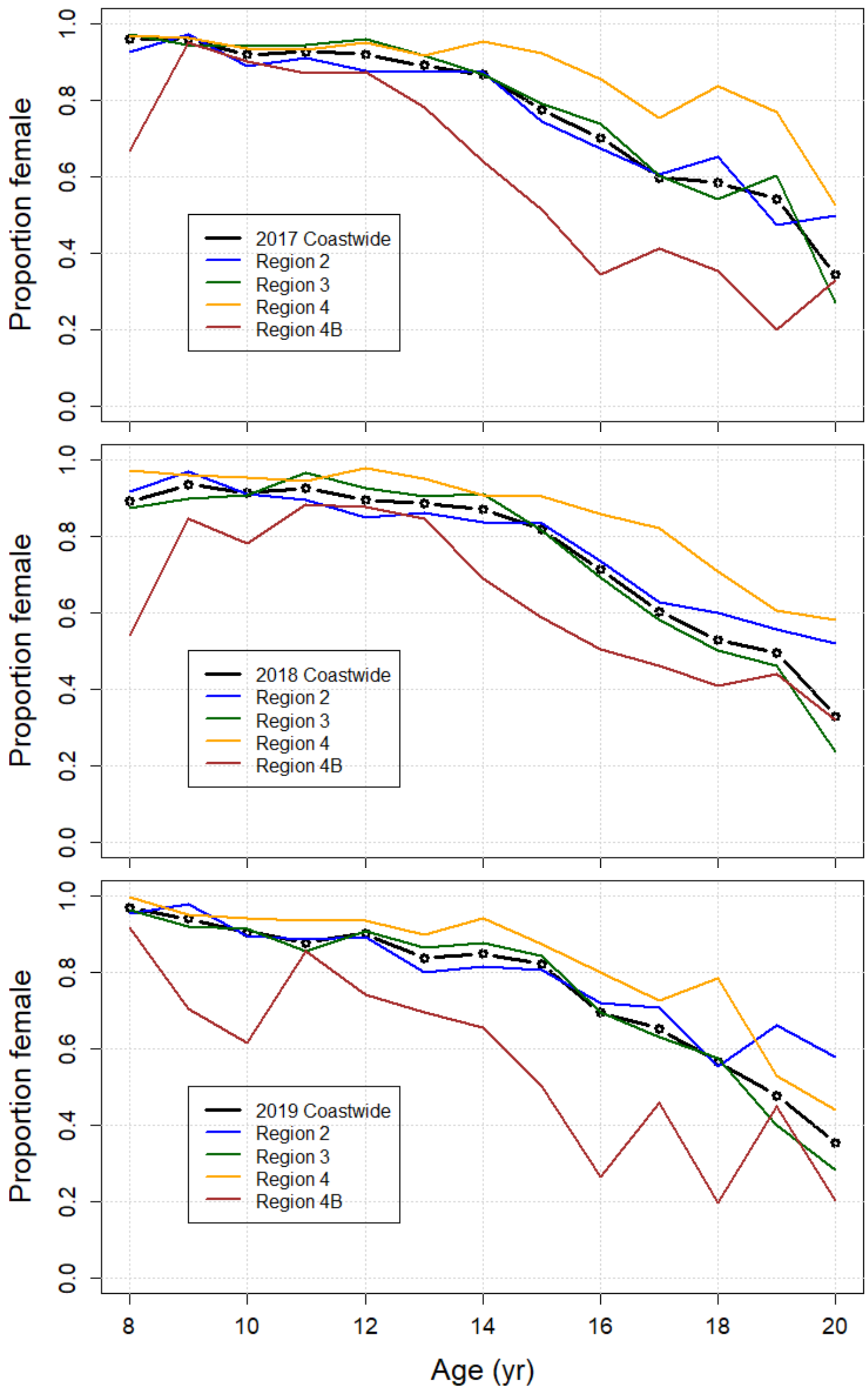

Figure 7. Commercial sex-ratios-at-age for 2017 (upper panel), 2018 (middle panel) and 2019 (lower panel) by Biological Region.

Table 2. Aggregate commercial fishery sex-ratios by Biological Region, 2017-2019.

	Coastwide	Biological Region 2	Biological Region 3	Biological Region 4	Biological Region 4B
2017	82%	82%	82%	92%	65%
2018	80%	82%	78%	91%	65%
2019	78%	80%	76%	89%	51%

Preliminary data updating existing sources

No additional preliminary data was available beyond the projected mortality for 2020. Additional data anticipated for the final 2020 stock assessment include:

1) New modelled trend information from the 2020 FISS including predictions covering both sampled and unsampled (but informed by covariates and the temporal correlation parameters) IPHC Regulatory Areas.
2) Age, length, individual weight, and average weight-at-age estimates from the 2020 FISS for all sampled IPHC Regulatory Areas.
3) 2020 (and a small amount of 2019) Commercial fishery logbook trend information from all IPHC Regulatory Areas.
4) 2020 Commercial fishery biological sampling (age, length, individual weight, and average weight-at-age) from all IPHC Regulatory Areas.
5) Biological information (lengths and/or ages) from non-directed discards (all IPHC Regulatory Areas) and the recreational fishery (IPHC Regulatory Area 3A only) from 2019.
6) Updated mortality estimates from all sources for 2019 (where preliminary values were used) and estimates for all sources in 2020.

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2020-SRB017-07 which provides a response to requests from SRB016 and a final update on model development for 2020.
b) **RECOMMEND** any further changes to be made for the final 2020 stock assessment.
c) **REQUEST** any additional analyses to be provided at SRB018, June 2021.

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