Update on the development of the 2021 stock assessment

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PURPOSE

To provide the IPHC's Scientific Review Board (SRB) a response to requests from SRB018 (IPHC-2021-SRB018-R) and to provide the Commission with an update on the development of the 2021 assessment.

INTRODUCTION

This document provides an update on stock assessment development progress since SRB018. As noted at that meeting (IPHC-2021-SRB018-06), the 2021 stock assessment represents an update of the 2020 assessment, with no major changes to the data or modelling structure planned. This document includes a response to requests from SRB018, as well as a brief summary of software updates, supplementary analyses, and new data for 2021.

SRB REQUESTS AND RESULTS

SRB018, the SRB made the following assessment requests:

SRB018 Req.4 (para. 24):

"The SRB REQUESTED an analysis of annual surplus production and the fraction of that production harvested."

Walters et al. (2008) suggested that surplus production plots be examined routinely as part of the stock assessment process. They note that the basic equation for surplus production (*S*) is simply a function of the estimated 'exploitable' biomass (*B*) from the stock assessment in year (*y*), and the total fishing mortality (*C*):

$$S_{y-1} = B_y - B_{y-1} + C_{y-1}$$

'Exploitable' biomass must be defined such that it relates to the catch. However, the stock assessment for Pacific halibut contains multiple multiple fisheries with differing and time-varying selectivity.

Therefore, the Secretariat considered five methods for evaluating the observed trends and scale of surplus production for Pacific halibut:

1) Previous work (from SRB05) fitting surplus production models directly to time-series data.
2) A 'standard' surplus production calculation based on the stock assessment results for all-ages biomass and observed total fishing mortality in each year.
3) The same calculation as (2) but based on the estimates of spawning biomass and observed total fishing mortality in each year.
4) Decision table results provided for the Commission from 2019-2021 (and interpolated in this analysis for earlier years) showing 3-year projections of surplus production in spawning biomass.

5) A model-free 'empirical harvest rate' calculation that has been provided to the Commission for evaluation each year beginning with the 2017 assessment.

Each of these methods and associated results are discussed below.

1. Fitting surplus production models

During 2014, the Secretariat explored a variety of alternative stock assessment models including Virtual Population Analysis (VPA), and classical surplus production models including Pella-Tomlinson, Schaefer, and Fox parameterizations. Results highlighted several important aspects of the Pacific halibut population dynamics and data that were not conducive to the use of these models. Particularly important is the relationship between biomass and surplus production: for Pacific halibut the largest estimated increase in yield (from approximately 1980-2000) was driven primarily by incoming recruitment. Further, the Fishery Independent Setline Survey (FISS) time-series only extends back to 1993, providing little information on the underlying relationship of biomass and productivity over most of the historical period. The lack of a strong stock-recruitment relationship, as well as the potential extrinsic effect of the Pacific Decadal Oscillation (PDO) being positively correlated with recruitment also make any relationship between biomass and surplus production difficult to detect. However, these models did suggest that Maximum Sustainable Yield (MSY) was around 40-45 million pounds (18-20 thousand mt), on a similar scale with the 100-year average yield of 63 million pounds (28.6 thousand mt).

2. Surplus production based on age-8+ biomass

For this first calculation of surplus production, the all-ages biomass was used to approximate the biomass that would be available to the fisheries. Some fish (predominantly males) are not available to some fisheries until older ages (> 10 for the directed commercial fishery), so this calculation is including a portion of the overall 'production' only available to smaller fisheries harvesting the youngest fish (age-2+ fish are present in the total yield as part of the non-directed discards and in recreational fisheries). The actual yield exceeds the estimated surplus in most of the recent time-series, consistent with the stock trend estimates of declining all-ages biomass over most of this period following historic highs in the late 1990s (Figure 1). As strong recruitments move into the population the surplus production based on all ages may peak earlier than when the majority of these fish are actually entering into the fishery.

The calculation and interpretation of surplus production may be somewhat confusing in the context of the IPHC's interim management procedure which is not designed to stabilize the total biomass at a specific level, but to apply a sustainable harvest rate ($SPR_{43\%}$), in tandem with a sloping control rule (30:20 in relative spawning biomass) such that long-term biological conservation objectives are met and fishery yield is optimized (IPHC-2021-AM097-11).

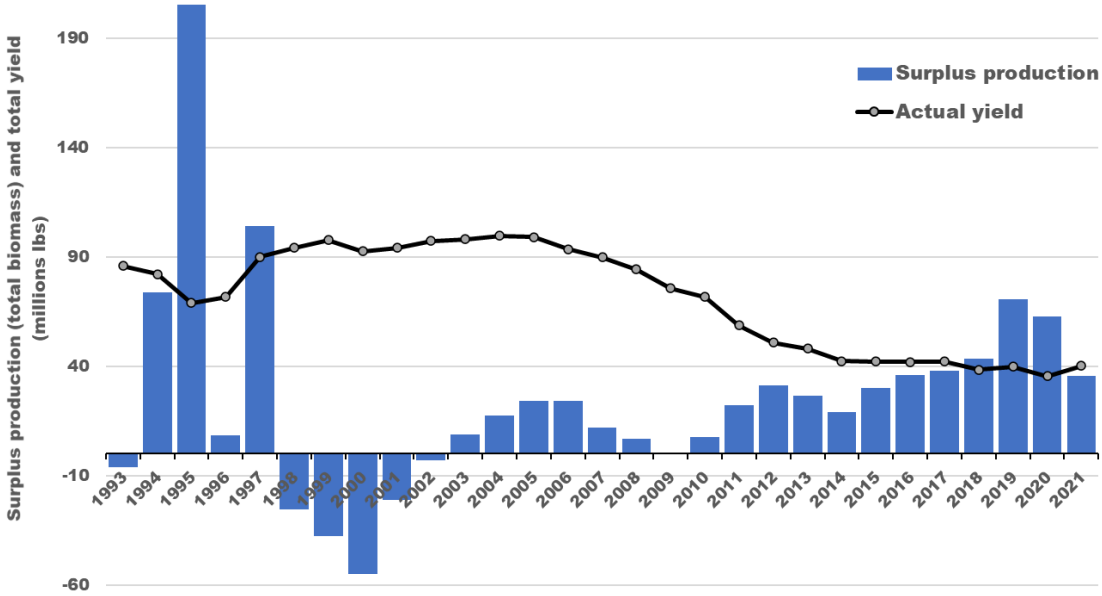

Figure 1. Actual yield (line) and estimated surplus production based on the all-ages biomass (bars). Where the surplus production exceeds the yield the stock is estimated to have increased in that year.

3. Surplus production based on spawning biomass

Following the same calculation used for total biomass, but instead using the spawning biomass to measure surplus production provides a smoother trend (Figure 2). Periods of positive surplus production seen when using spawning biomass tend to lag those seen in total biomass (Figure 1). Surplus production based on spawning biomass provides an interpretation that is perhaps more relevant to the Commission's management reference points. It is clear from these results that the fishery exceeded the surplus production in the spawning biomass from 1998-2010, a period of continuous stock decline. From 2011-2017 yield and surplus production were similar, and then surplus production has again been exceeded over 2018-2021. These results are consistent with the high probability of stock decline estimated in each year's stock assessment over this later period, and the Commission's decisions to follow a 'fishing-down' policy over this period, while maintaining the target harvest rate ($SPR_{46\%}$, and then $SPR_{43\%}$ beginning in 2021).

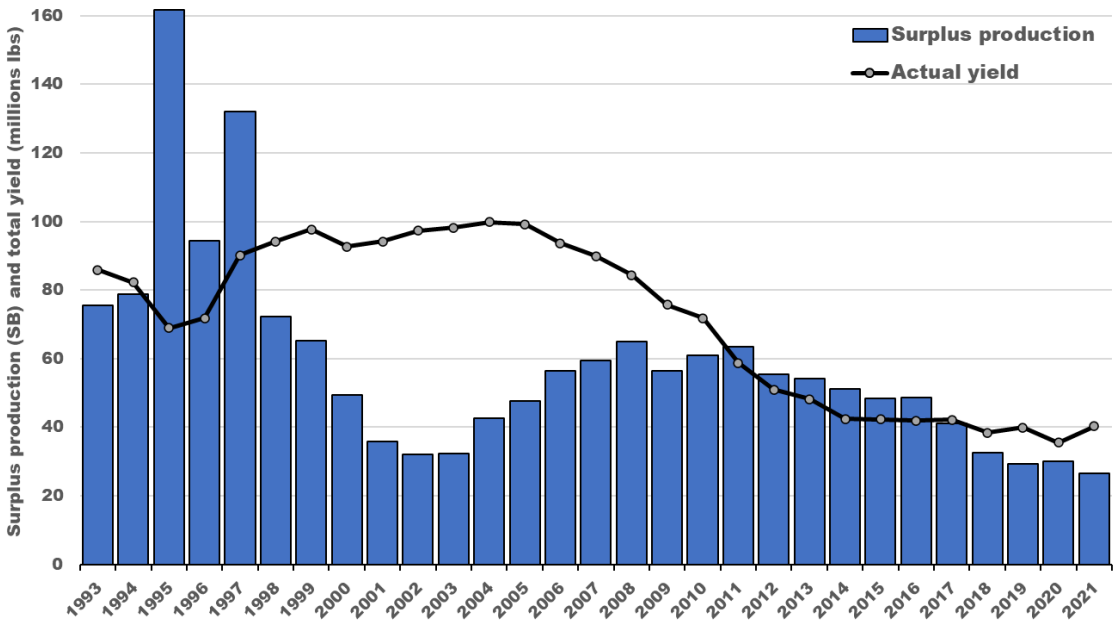

Figure 2. Actual yield (line) and estimated surplus production based on the spawning biomass (bars). Where the surplus production exceeds the yield the stock is estimated to have increased in that year.

4. Decision table-based surplus production

Beginning with the 2019 stock assessment the harvest decision table summarizing the results of the annual stock assessment has included a 3-year 'surplus production' calculation for comparison with other management alternatives (Table 1). This calculation differs importantly from the annual surplus production described above in that it reports the yield (in TCEY and total mortality) that can be taken for the next 3 years that would result in an estimated 50% chance of decrease in spawning biomass. Thus, even though the Commission currently uses an annual mortality limit setting process, this column provides a projection of the yield available in the near-term that would not adversely affect the spawning stock. Anecdotal response to this information indicates that it has been helpful as a comparison to the management procedure, and to put in context the yield that is set for the upcoming year.

Using the calculated probabilities in earlier harvest decision tables, an interpolation was made to approximate the 3-year surplus back to the 2012 stock assessment (Figure 4). As the Commission did not use the TCEY prior to the 2017 stock assessment (providing the 2018 3-year calculation), the total mortality is used for comparison with more recent stock assessments. Similar to the one-year surplus calculations reported above, the yield approached parity with surplus production in 2015-2016 (noting that the three-year calculation is somewhat lower based on subsequent stock declines) and then has exceeded the 3-year surplus for 2017+.

Table 1. Harvest decision table for 2021 mortality limits (provided at AM097; IPHC-2021-AM097-08). Columns correspond to yield alternatives and rows to risk metrics. Values in the table represent the probability, in "times out of 100" (or percent chance) of a particular risk.

2021 Alternative				3-Year Surplus		Status quo		*Reference* $F_{43\%}$					
Total mortality (M lb)			0.0	25.7	36.8	37.9	39.1	40.3	41.5	42.9	44.1	61.3	
TCEY (M lb)			0.0	24.4	35.5	36.6	37.8	39.0	40.3	41.6	42.8	60.0	
2021 fishing intensity			$F_{100\%}$	$F_{58\%}$	$F_{46\%}$	$F_{45\%}$	$F_{44\%}$	$F_{43\%}$	$F_{42\%}$	$F_{41\%}$	$F_{40\%}$	$F_{30\%}$	
Fishing intensity interval			--	39-76%	29-65%	29-64%	28-63%	27-62%	26-61%	26-60%	25-59%	18-49%	
Stock Trend (spawning biomass)	in 2022	is less than 2021	<1	42	61	62	64	65	66	67	69	82	a
		is 5% less than 2021	<1	7	32	34	36	39	41	44	46	66	b
	in 2023	is less than 2021	<1	51	62	63	64	65	66	67	69	81	c
		is 5% less than 2021	<1	32	53	54	55	56	57	59	59	74	d
	in 2024	is less than 2021	<1	50	60	61	62	63	64	66	67	80	e
		is 5% less than 2021	<1	40	55	56	57	57	58	59	60	74	f
Stock Status (Spawning biomass)	in 2022	is less than 30%	29	35	39	40	40	41	41	42	42	47	g
		is less than 20%	<1	<1	<1	<1	1	1	1	1	1	4	h
	in 2023	is less than 30%	23	32	39	40	40	41	42	43	43	49	i
		is less than 20%	<1	<1	2	2	3	3	4	5	5	19	j
	in 2024	is less than 30%	12	29	38	39	40	41	42	43	44	50	k
		is less than 20%	<1	<1	4	5	6	8	9	10	12	25	l
Fishery Trend (TCEY)	in 2022	is less than 2021	0	17	48	49	50	50	50	51	51	77	m
		is 10% less than 2021	0	6	41	44	46	48	49	50	50	63	n
	in 2023	is less than 2021	0	21	49	50	50	50	50	51	51	75	o
		is 10% less than 2021	0	11	45	47	48	49	50	50	50	64	p
	in 2024	is less than 2021	0	23	49	50	50	50	50	51	51	74	q
		is 10% less than 2021	0	13	47	48	49	49	50	50	50	64	r
Fishery Status (Fishing intensity)	in 2021	is above $F_{43\%}$	0	15	48	49	50	50	50	51	51	78	s

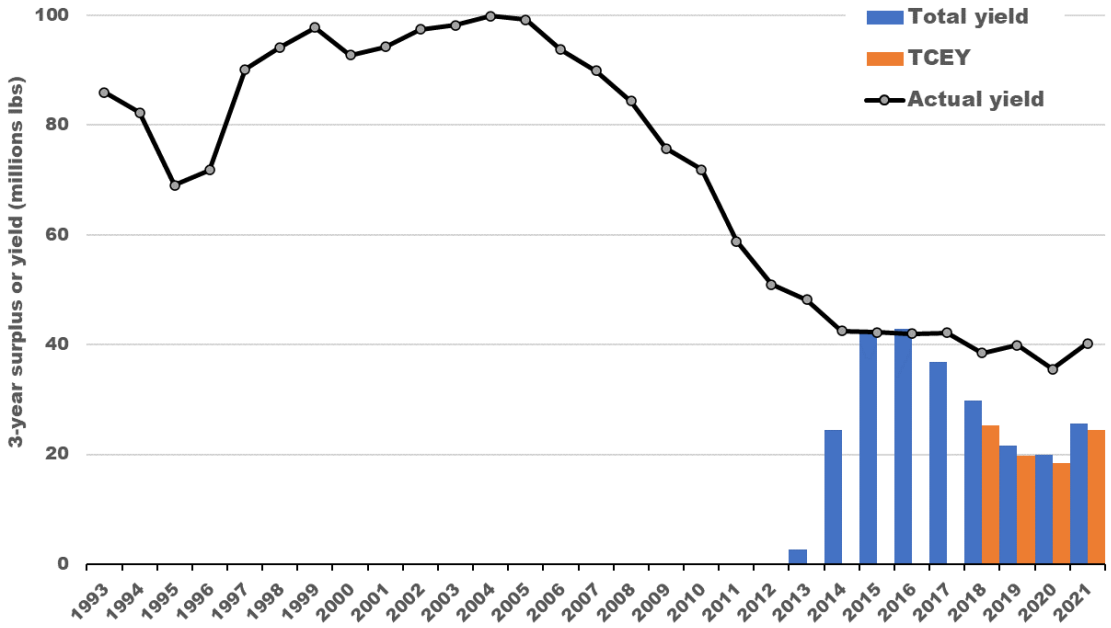

Figure 3. Actual yield (line) and 3-year projected surplus production based on the TCEY (orange bars) and total mortality (blue bars).

5. Empirical harvest rates

Beginning in 2017, the Secretariat developed a model-free method to evaluate the relationship between FISS indices and fishing mortality. This simple method provides an empirical approach for evaluating relative harvest rates based solely on data (rather than stock assessment output). A measure of exploitation (*U*) in each year (*y*) and Biological Region (*r*) can be based on the O26 mortality (Pacific halibut >= 26 inches, 66 cm, in length; 'catch': *C*) and some measure of the biomass (*B*):

$$U_{y,r} \sim \frac{C_{y,r}}{B_{y,r}}$$

The biomass is a function of the modelled survey index (*I*) and an unknown catchability parameter (*q*):

$$B_{y,r} = q_{y,r} \cdot I_{y,r}$$

Finally, the survey index is a function of the modelled survey WPUE of all sizes of Pacific halibut (primarily O26), and the geographic extent (*A*) of each Biological Region:

$$I_{y,r} = WPUE_{y,r} \cdot A_r$$

O26 mortality is used in this calculation as it corresponds most closely to the TCEY, or the mortality limit set by the Commission. In this calculation, it is assumed that the catchability parameter is constant (or at least that variation is random) across years and among Biological Regions (note that the FISS timing and station-specific hook competition are already accounted for in the space-time modelling of WPUE; IPHC-2021-AM097-07). Since the absolute scale of

the exploitation is unknown, an arbitrary scalar (*k*) is used to make the results easily interpretable, leaving the estimated relative exploitation ($\widehat{U}$) as:

$$\widehat{U}_{y,r} = \frac{C_{y,r}}{I_{y,r}} k$$

An arbitrary value of *k* was used that resulted in the coastwide aggregate in the terminal year taking a value of 1.0. Much higher *U* values are estimated for Biological Region 2 than in other Regions; however, all Regions experienced peak harvest rates between 2003 and 2009 (Figure 4). The harvest rates in all Biological Regions were generally lower than most historical values over the period 2012 -2014, and then increased in Regions 2-3 during 2017-20. These coastwide results are generally consistent with those from the surplus production analyses described above, and also provide a corroboration of Region-specific harvest rate trends that does not rely on assessment model output.

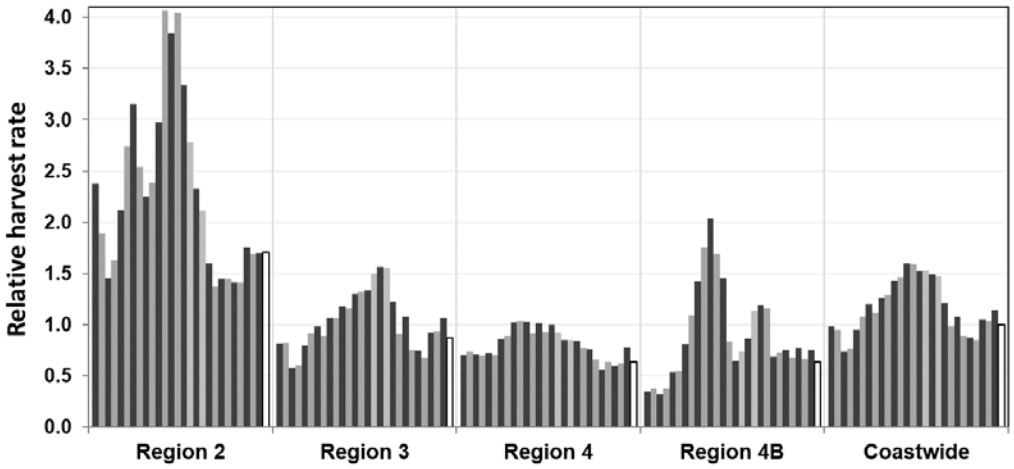

Figure 4. Empirical harvest rates from 1993-2020. All rates are relative to the coastwide aggregate in the terminal year (open bars), which is arbitrarily set equal to 1.0.

SOFTWARE UPDATES

As described for SRB018, the stock synthesis software was updated in the spring of 2021 to version 3.30.16.02 (Methot Jr et al. 2020), which resulted in no change to results, but an increase in model run times. A newer version (3.30.17.00) is now available (Methot Jr et al. 2021). Updating to this version again produced no change in model results, but improved run times to be consistent with older versions and will be used for the 2021 stock assessment. Keeping the Pacific halibut assessment models current will make future transitions easier and facilitate development during the next full assessment.

ADDITIONAL STOCK ASSESSMENT DEVELOPMENT IN 2021

During 2021 the Secretariat has begun exploration of marine mammal depredation reported in commercial fishery logbooks. New fields were included in the 2017 and 2018 fishery logbooks (depending on the IPHC Regulatory Area and whether a new log was requested/required) allowing for the documentation of marine mammal encounters (primarily orca and sperm whales)

during directed commercial Pacific halibut fishing. The specific information requested includes: the type and number of marine mammals observed (if any), and the type and extent of gear and/or catch damage observed (if any). Based on analysis of FISS data, gear or catch damage is often indicative of depredation. From these records it will be possible to estimate the frequency with which the directed commercial fishery is encountering marine mammals and therefore potentially experiencing depredation. They may also allow for the development of indicators of the degree of depredation that is occurring, including the change in Catch-Per-Unit-Effort (CPUE) relative to nearby fishing that occurred in the absence of whale activity. As these data have not been previously analyzed, an extensive effort is being made to evaluate the consistency and accuracy of the data collection, as well as the formatting of the information in IPHC databases. Preliminary results may be available for presentation at SRB019.

PRELIMINARY DATA UPDATES

No preliminary data were available from 2021 in time for inclusion in this document. Standard data sources that will be included in the final 2021 stock assessment include:

1) New modelled trend information from the 2021 FISS for all IPHC Regulatory Areas.
2) Age, length, individual weight, and average weight-at-age estimates from the 2021 FISS.
3) 2021 (and a small amount of 2020) Directed commercial fishery logbook trend information from all IPHC Regulatory Areas.
4) 2021 Directed commercial fishery biological sampling (age, length, individual weight, and average weight-at-age) from all IPHC Regulatory Areas.
5) Directed commercial fishery sex-ratio-at-age data from the 2020 fishery (extending the series to four years: 2017-2020) are anticipated to be available prior to SRB2019. Preliminary summary and models fitted to these data may be presented if time-permits.
6) Biological information (lengths and/or ages) from non-directed discards (all IPHC Regulatory Areas) and the recreational fishery (IPHC Regulatory Area 3A only) from 2020.
7) Updated mortality estimates from all sources for 2020 (where preliminary values were used) and estimates for all sources in 2021.

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2021-SRB019-06 which provides a response to requests from SRB018, and an update on model development for 2021.
b) **RECOMMEND** any changes to be included in the final 2021 stock assessment to be completed for presentation at IM097, 30 November – 1 December 2021.
c) **REQUEST** any further analyses to be provided at SRB020, June 2021.

REFERENCES

Hicks, A., Carpi, P., Stewart, I., and Berukoff, S. 2021. IPHC management strategy evaluation for Pacific halibut (*Hippoglossus stenolepis*). IPHC-2021-AM097-11. 49 p.

IPHC. 2021. Report of the 18th session of the IPHC Scientific Review Board (SRB018). IPHC-2021-SRB018-R. 21 p.

Methot Jr, R.D., Wetzel, C.R., Taylor, I.G., and Doering, K. 2020. Stock synthesis user manual version 3.30.16. NOAA Fisheries. 225 p.

Methot Jr, R.D., Wetzel, C.R., Taylor, I.G., Doering, K.L., and Johnson, K.F. 2021. Stock synthesis user manual version 3.30.17. NOAA Fisheries, Seattle, WA. 238 p.

Stewart, I., and Hicks, A. 2021. 2021 Pacific halibut (*Hippoglossus stenolepis*) stock assessment development. IPHC-2021-SRB018-06. 14 p.

Stewart, I., Hicks, A., Webster, R., and Wilson, D. 2021. Stock assessment: Summary of the data, stock assessment, and harvest decision table for Pacific halibut (*Hippoglossus stenolepis*) at the end of 2020. IPHC-2021-AM097-08. 19 p.

Walters, C.J., Hilborn, R., and Christensen, V. 2008. Surplus production dynamics in declining and recovering fish populations. Canadian Journal of Fisheries and Aquatic Sciences **65**: 2536-2551.