Summary of the data, stock assessment, and harvest decision table for Pacific halibut (*Hippoglossus stenolepis*) at the end of 2018

PREPARED BY: IPHC SECRETARIAT (I. STEWART, A. HICKS, R. WEBSTER, AND D. WILSON; 20 NOVEMBER 2018)

PURPOSE

To provide the Commission with a summary of the data, stock assessment, and harvest decision table at the end of 2018.

INTRODUCTION

In 2018 the International Pacific Halibut Commission (IPHC) undertook its annual coastwide stock assessment of Pacific halibut (*Hippoglossus stenolepis*) using a range of updated data sources. This summary provides an overview of the data sources available for the Pacific halibut stock assessment and related analyses including the population trends and biological stock distribution based on the IPHC fishery-independent setline survey and the results of the 2018 stock assessment. Alternative mortality projections can be evaluated via the online mortality projection tool (https://iphc.int/data/projection-tool).

STOCK AND MANAGEMENT

The stock assessment reports the status of the Pacific halibut (*Hippoglossus stenolepis*) resource in the IPHC Convention Area. As in recent stock assessments, the resource is modelled as a single stock extending from northern California to the Aleutian Islands and Bering Sea, including all inside waters of the Strait of Georgia and Puget Sound, but excludes known extremities in the western Bering Sea within the Russian Exclusive Economic Zone (Figure 1).

The Pacific halibut fishery has been managed by the IPHC since 1923. Catch limits for each of eight management Regulatory Areas[1] are set each year by the Commission. The stock assessment provides a summary of recently collected data, and model estimates of stock size and trend. Specific management information is summarized via a decision table reporting the estimated risks associated with alternative management actions and mortality tables projecting detailed summaries for fisheries in each Regulatory Area indicated by the IPHC's interim management procedure, as well as other alternatives.

[1] The IPHC recognizes sub-Areas 4C, 4D, 4E and the Closed Area for use in domestic catch agreements but manages the combined Area 4CDE.

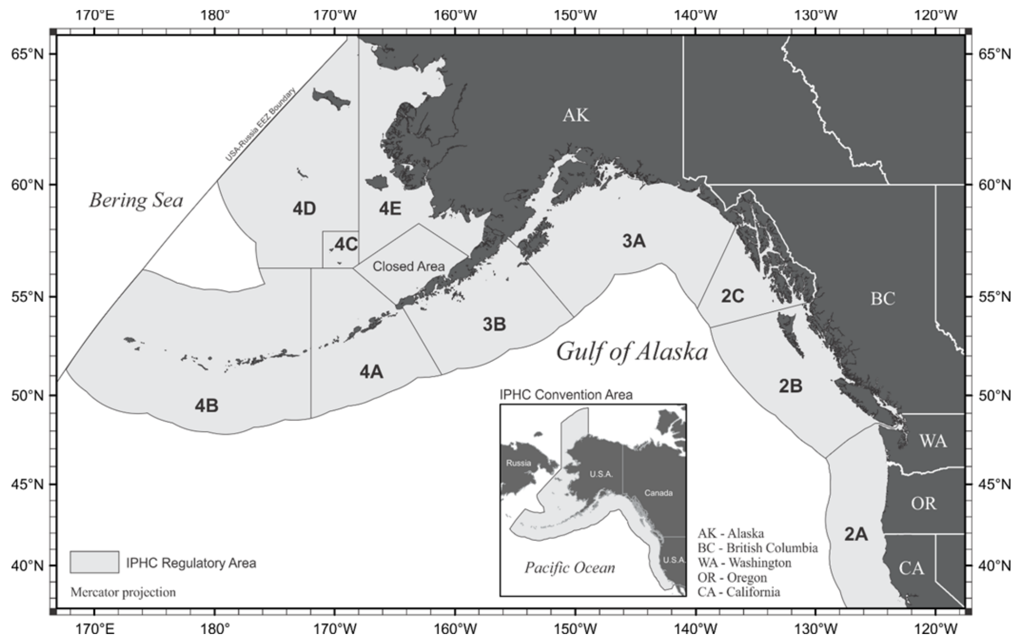

FIGURE 1. IPHC Regulatory Areas and the Pacific halibut geographical range within the territorial waters of Canada and the United States of America.

DATA

Historical mortality

Known Pacific halibut mortality consist of target commercial fishery landings and discard mortality (including research), recreational fisheries, subsistence, and bycatch mortality in fisheries targeting other species (where Pacific halibut retention is prohibited). Over the period 1919-2018 removals have totaled 7.2 billion pounds (~3.3 million metric tons, t), ranging annually from 34 to 100 million pounds (16,000-45,000 t) with an annual average of 63 million pounds (~29,000 t; Figure 2). Annual removals were above this long-term average from 1985 through 2010, were relatively stable near 42 million pounds (~19,000 t) from 2014-17 and decreased by 8% in 2018.

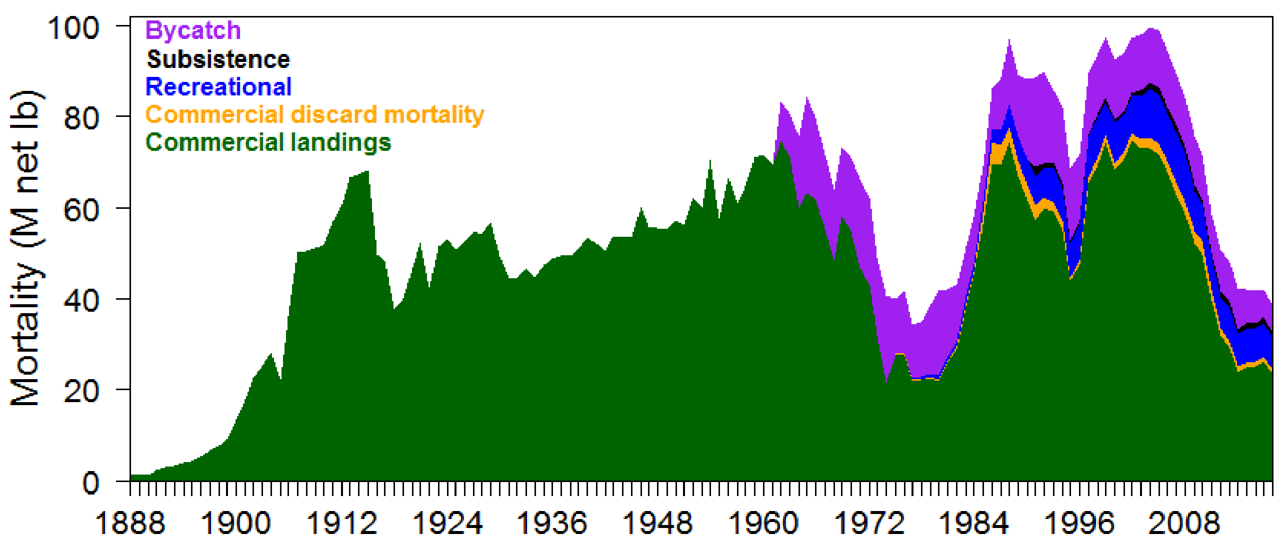

FIGURE 2. Summary of estimated historical mortality by source (colors), 1888-2018.

2018 Fishery and IPHC fishery-independent setline survey (FISS) statistics

Coastwide commercial Pacific halibut fishery landings in 2018 were approximately 23.5 million pounds (~10,660 t), a low for the last decade. Bycatch mortality was estimated to be 6.1 million pounds in 2018 (~2,750 t)[2], the lowest level in the estimated time series, beginning with the arrival of foreign fishing fleets in 1962, and 99.8% of the magnitude estimated for 2017. The total recreational mortality was estimated to be 7.2 million pounds (~3,260 t), down 5% from 2017. Mortality from all sources in 2018 was estimated to be 38.7 million pounds (~17,570 t).

Data are initially compiled by IPHC Regulatory Area, and then aggregated to four biological Regions: Region 2 (Areas 2A, 2B, and 2C), Region 3 (Areas 3A, 3B), Region 4 (4A, 4CDE) and Region 4B and then coastwide (Figure 1). In addition to the aggregate mortality (including all sizes of Pacific halibut), the assessment includes data from both fishery dependent and fishery independent sources as well as auxiliary biological information, with the most spatially complete data available since the late-1990s. Primary sources of information for this assessment include modelled indices of abundance (**IPHC-2018-IM094-07**) from the IPHC's annual fishery-independent setline survey (FISS; in numbers and weight), commercial Catch-Per-Unit-Effort (weight), and biological summaries from both sources (length-, weight-, and age-composition data).

All data sources are reprocessed each year to include new information from the terminal year, as well as any additional information for or changes made to the entire time-series. For 2018, additional data included: a revised index of abundance reflecting the FISS sampling and expansion and space-time modelling of these data conducted in 2018, logbook records from the 2017-18 directed commercial fishery, as well as age-frequency observations from both sources. Since 2015, individual Pacific halibut weights collected during port sampling of commercial fishery landings are used to describe the commercial fishery. (1993-97 and 2017). All mortality estimates (including changes to the existing time-series were new estimates have become available) were extended to include 2018. All available information was finalized on 9 November 2018 in order to provide adequate time for analysis and modeling. As has been the case in all years, some data are incomplete (i.e. commercial fishery logbook and age information), or include projections for the remainder of 2017 (i.e. mortality estimates for ongoing fisheries or for fisheries where final estimation is still pending).

The 2018 FISS detailed a coastwide aggregate NPUE (modelled via the space-time methodology) which was showed a second consecutive year of decrease, down 7% from 2017, with individual Biological Regions ranging from a 6% increase (Region 4B) to a 15% decrease (Region 2; Figure 3). The WPUE of legal (O32) Pacific halibut, the most comparable metric to observed commercial fishery catch rates was 5% lower than the 2017 estimate at the coastwide level, constituting the lowest value in the time series. Individual IPHC Regulatory Areas varied from a 12% increase (Regulatory Area 4B) to a 19% decrease (Regulatory Area 2C; Figure 4). The FISS sampling associated with the expansion in Region 2 (Regulatory Areas 2A, 2B, and 2C) revised the estimated relative catch-rates in this region compared to the rest of the coast, and reduced the variability about the estimates by approximately 48%.

[2] The IPHC receives preliminary estimates of the current year's bycatch mortality in from the NOAA-Fisheries National Marine Fisheries Service Alaska Regional Office, Northwest Fisheries Science Center, and Fisheries and Oceans Canada in late October.

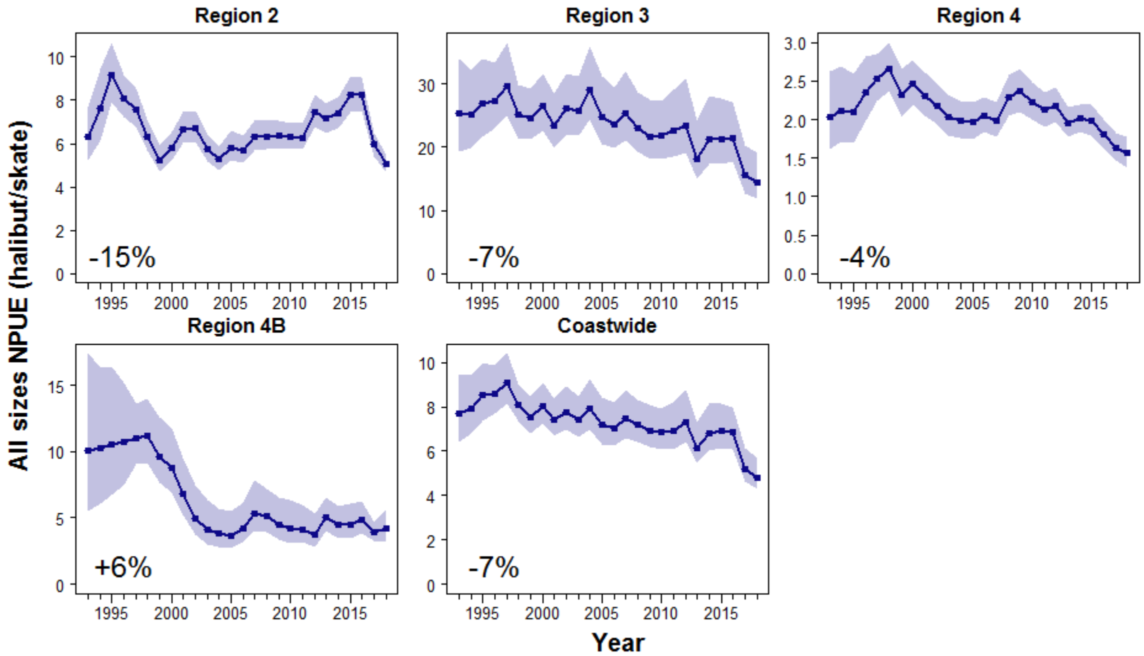

FIGURE 3. Trends in FISS NPUE by Biological Region, 1993-2018. Percentages indicate the change from 2017 to 2018. Shaded zones indicate approximate 95% credible intervals.

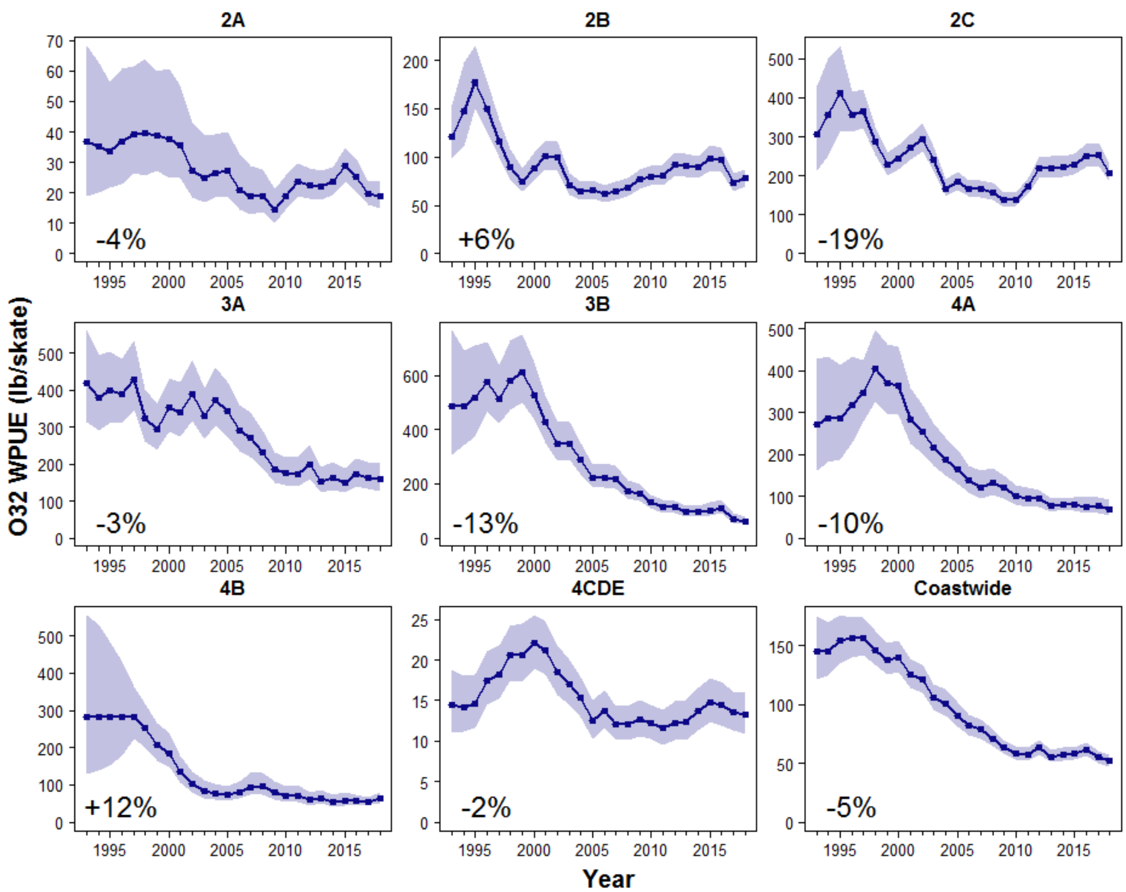

FIGURE 4. Trends in FISS legal (O32) WPUE by IPHC Regulatory Area, 1993-2018. Percentages indicate the change from 2017 to 2018. Shaded zones indicate approximate 95% credible intervals.

Commercial fishery WPUE (based on extensive, but incomplete logbook records available for this assessment) decreased 11% at the coastwide level with most fisheries, gears and areas decreasing from the 2017 estimates. A bias correction for each IPHC Regulatory Area based on the last six years of resulting from additional logbooks available after the assessment deadline in early November resulted in an estimate of a 13% decrease coastwide and negative trends for all Regulatory Areas except Area 2A (+5%) and 4B (+2%). In addition to reporting tribal and non-tribal commercial fishery trends in Regulatory Area 2A separately, catch-rates reported for snap gear and fixed-hook gear are also delineated for comparison (Figure 5).

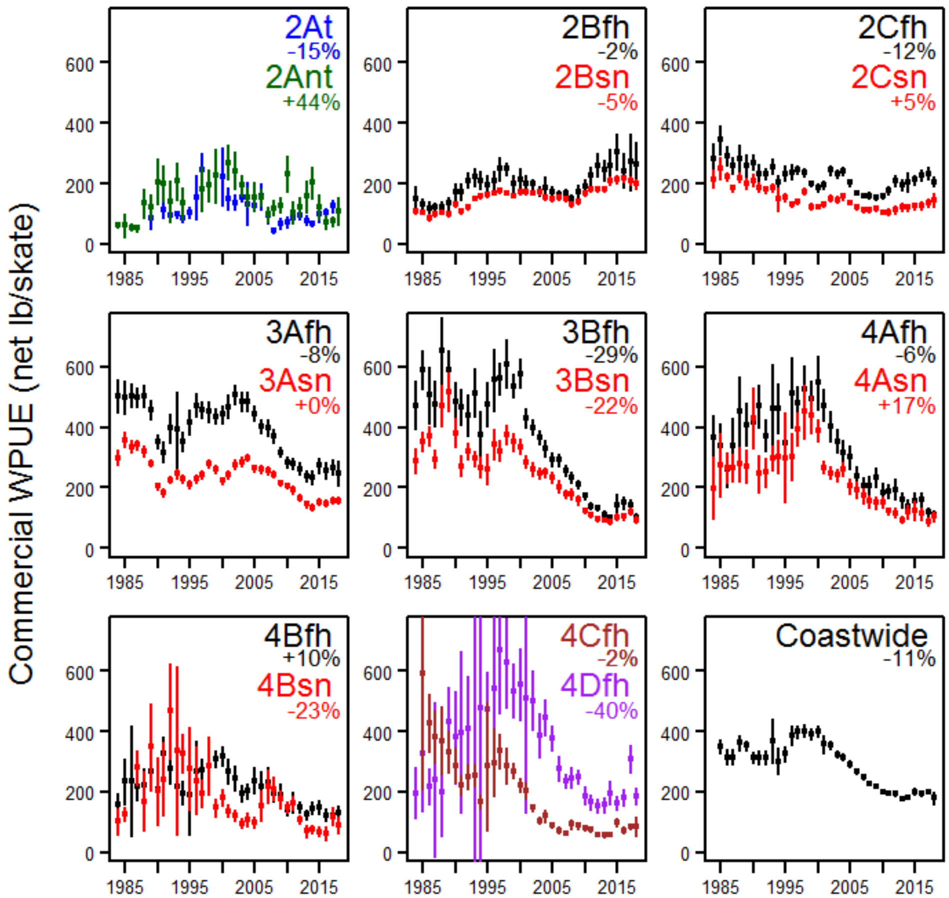

FIGURE 5. Trends in commercial fishery WPUE by Regulatory Area and fishery or gear, 1984-2018. The tribal fishery in 2A is denoted by “2At”, nontribal by “2Ant”, fixed hook catch rates by “fh” and snap gear catch rates by “sn” for IPHC Regulatory Areas 2B-4D. Percentages indicate the change from 2017 to 2018 uncorrected for bias due to incomplete logbooks (see text above). Vertical lines indicate approximate 95% confidence intervals.

Biological information from both the commercial fishery and FISS continue to show the 2005 year-class as the largest contributor (in number) to the fish encountered. Relatively weak cohorts have been observed in the age-frequency data from 2006-10. In 2018, the FISS encountered an increased number of 6-7 year-old Pacific halibut (the 2011 and 2012 year-classes), although the apparent strength of these cohorts varied spatially. At the coastwide level, individual size-at-age continues to be very low relative to the rest of the time-series and there has been little apparent change over the last several years.

Biological stock distribution

Trends over the last five years indicate that population distribution (measured via all Pacific halibut captured on the FISS) has been relatively stable among biological Regions (Figure 6, Table 1), with approximately half of the stock occurring in Region 3, one quarter in Region 2 and one quarter in Regions 4 and 4B. Both Regions 4 and 4B appear to be increasing slowly over this period. Over a decadal time-period (setline survey data prior to 1993 is insufficient to provide stock distribution estimates) there has been an increasing proportion of the coastwide stock occurring in Region 2 and a decreasing proportion occurring in Region 3. It is unknown to what degree either of these periods corresponds to historical distributions (before the mid-1990s) or to the average distribution likely to occur in the absence of fishing mortality. In 2018, the proportion of the stock estimated to be located in Region 2 decreased, and all other Regions increased.

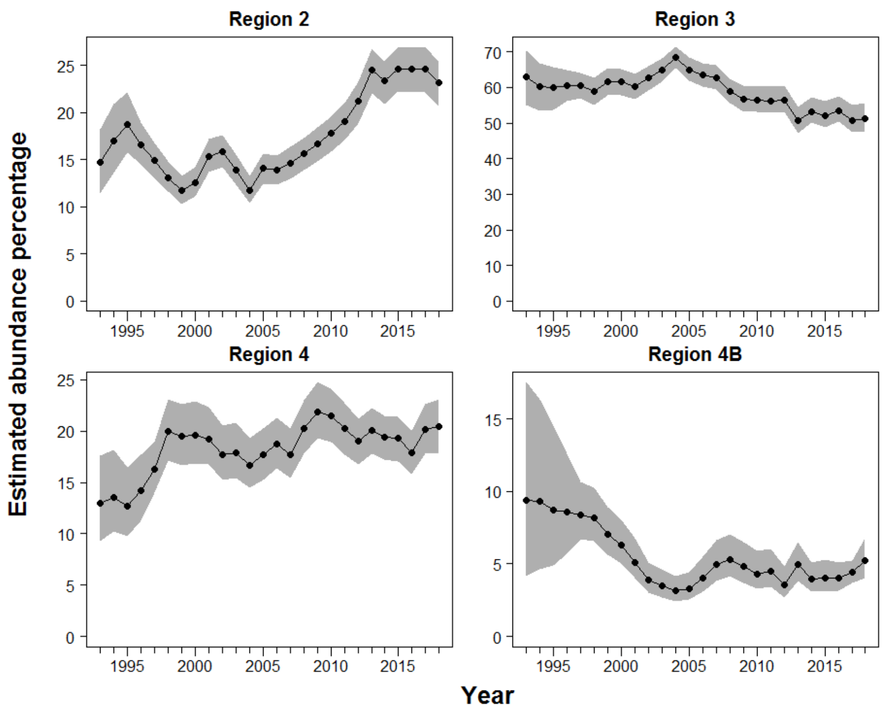

FIGURE 6. Estimated stock distribution (1993-2017) based on setline survey catch of O32 (black series) and all sizes (blue series) of Pacific halibut. Shaded zones indicate approximate 95% credible intervals.

TABLE 1. Recent regional stock distribution estimates based on modelling of all Pacific halibut captured by the IPHC fishery-independent setline survey.

Year	Region 2 (2A, 2B, 2C)	Region 3 (3A, 3B)	Region 4 (4A, 4CDE)	Region 4B
2014	23.4%	53.3%	19.4%	4.0%
2015	24.6%	52.1%	19.3%	4.0%
2016	24.6%	53.5%	17.9%	4.0%
2017	24.6%	50.8%	20.2%	4.4%
2018	23.1%	51.2%	20.4%	5.2%

STOCK ASSESSMENT

Consistent with the analyses from 2015-17, this stock assessment is implemented using the generalized software stock synthesis (Methot Jr and Wetzel 2013). The analysis consists of an ensemble of four equally weighted models: two long time-series models, reconstructing historical dynamics back to the beginning of the modern fishery, and two short time-series models incorporating data only from 1996 to the present, a time-period for which estimates of all sources of mortality and survey indices are available for all regions. For each time-series length, there are two models: one fitting to coastwide aggregate data, and one fitting to data disaggregated into the four geographic regions. This combination of models includes uncertainty in the form of alternative hypotheses about several important axes of uncertainty, including: natural mortality rates (estimated in the long time-series models, fixed in the short time-series models), environmental effects on recruitment (estimated in the long time-series models), the stock-recruitment relationship (specified in the long time-series models, freely estimated in the short time-series models), and other model parameters.

As has been the case since 2012, the results of this stock assessment are based on the approximate probability distributions derived from the ensemble of models, thereby incorporating the uncertainty within each model (parameter or estimation uncertainty) as well as the uncertainty among models (structural uncertainty). This approach reduces the potential for abrupt changes in management quantities as improvements and additional data are added to individual models, and provides a more realistic perception of uncertainty than any single model, and therefore a stronger basis for risk assessment. For 2018, the four models were again equally weighted; work-to-date on retrospective and predictive performance continues to suggest that each can be considered approximately equally plausible. Within-model uncertainty from each model was propagated through to the ensemble results via the maximum likelihood estimates and an asymptotic approximation to their variance. Point estimates in this stock assessment correspond to median values from the ensemble: with the simple probabilistic interpretation that there is an equal probability above or below the reported value.

BIOMASS AND RECRUITMENT TRENDS

The results of the 2018 stock assessment indicate that the Pacific halibut stock declined continuously from the late 1990s to around 2011 (Figure 7). That trend is estimated to have been largely a result of decreasing size-at-age, as well as somewhat weaker recruitment strengths than those observed during the 1980s. Since the estimated female spawning biomass (SB) stabilized near 190 million pounds (~86,200 t) in 2011, the stock is estimated to have increased gradually to 2016. The SB at the beginning of 2019 is estimated to be 199 million pounds (~90,300 t), with an approximate 95% confidence interval ranging from 125 to 287 million pounds (~56,700-130,200 t; Figure 8). Comparison with previous stock assessments indicates that the 2017 results are very close to estimates from the 2012 through 2017 assessments, all of which lie very close to the median estimate (Figure 9.). The 2018 SB estimate from the 2018 stock assessment is only 1% larger the estimate from the 2017 stock assessment. However, the uncertainty is larger as the effects of the revised time-series in Region 2 influenced each of the individual models differently, and resulted in a greater difference in the magnitude of the terminal year's estimated spawning biomass.

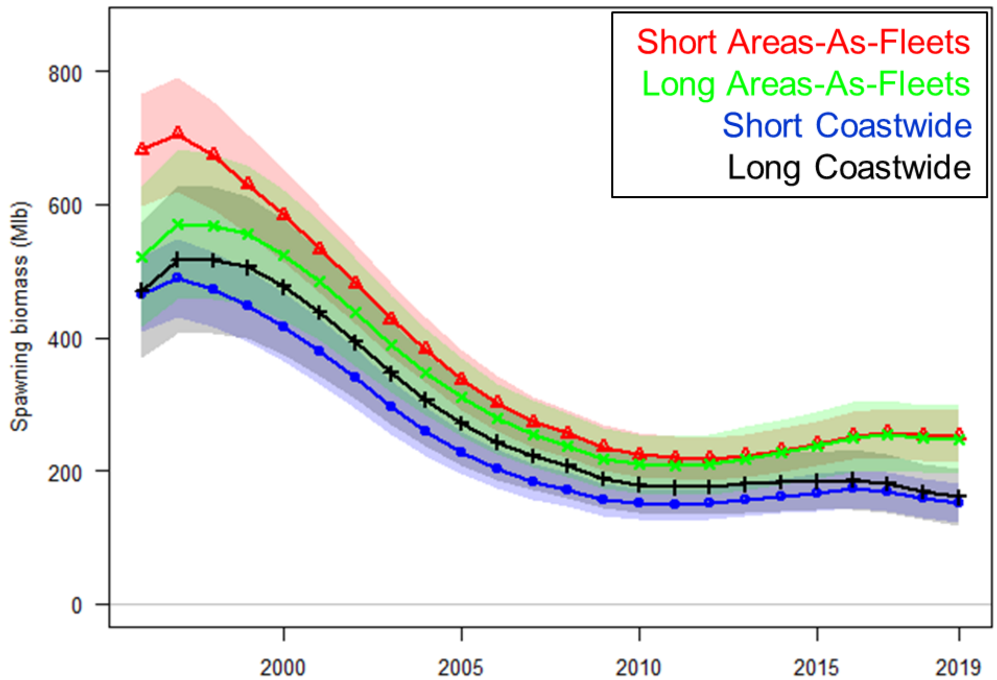

FIGURE 7. Estimated spawning biomass trends (1996-2019) based on the four individual models included in the 2018 stock assessment ensemble. Series indicate the maximum likelihood estimates; shaded intervals indicate approximate 95% credible intervals.

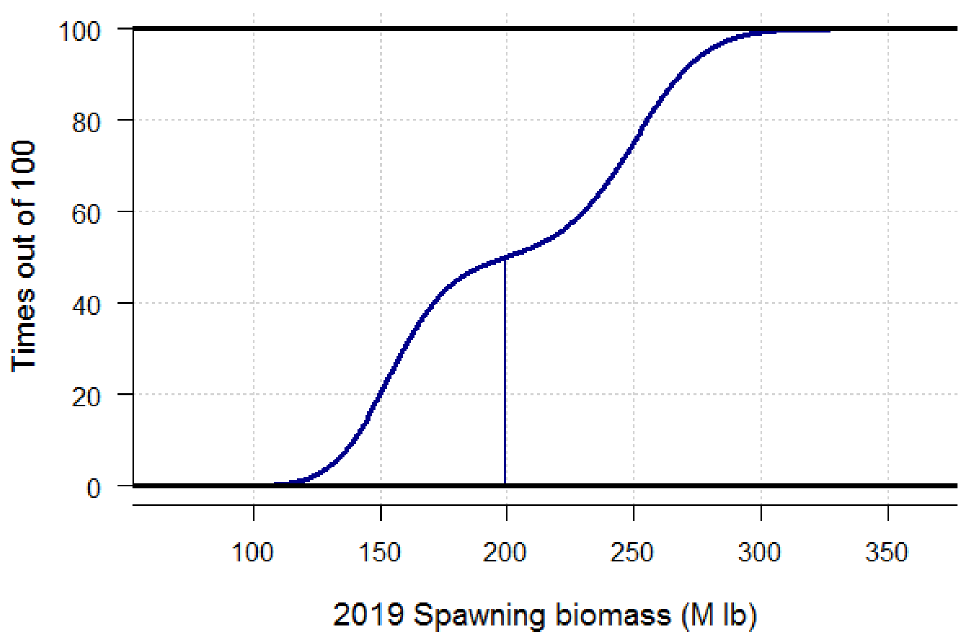

FIGURE 8. Cumulative distribution of the estimated spawning biomass at the beginning of 2019. Curve represents the estimated probability that the biomass is less than or equal to the value on the x-axis; vertical line represents the median (199 million pounds; ~90,300 t).

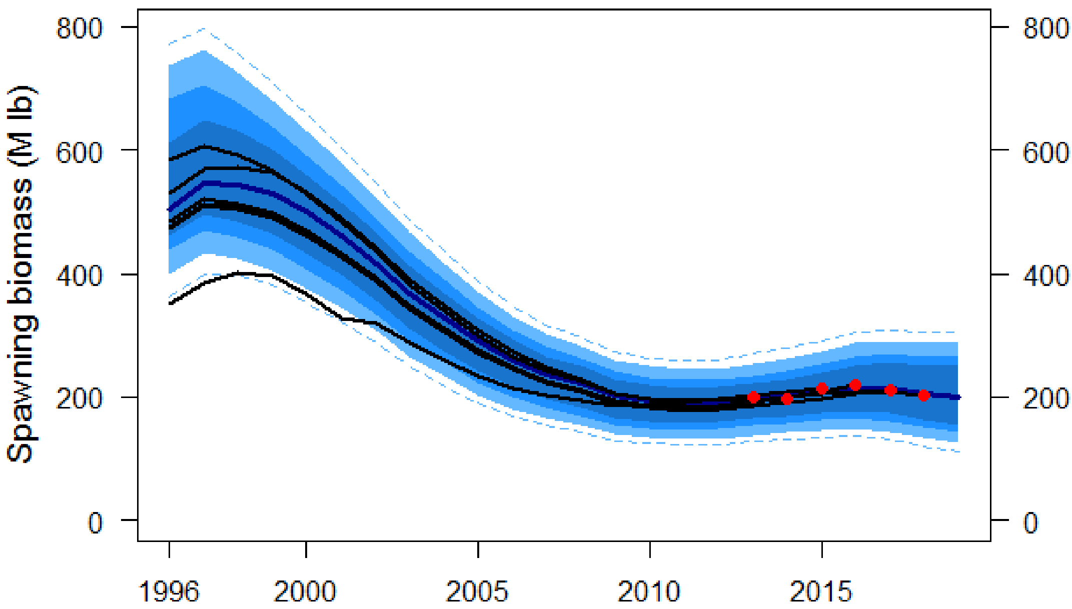

FIGURE 9. Retrospective comparison among recent IPHC stock assessments. Black lines indicate estimates of spawning biomass from assessments conducted from 2012-2017 with the terminal estimate shown as a point, the shaded distribution denotes the 2018 ensemble: the dark blue line indicates the median (or “50:50 line”) with an equal probability of the estimate falling above or below that level; colored bands moving away from the median indicate the intervals containing 50/100, 75/100, and 95/100 estimates; dashed lines indicating the 99/100 interval.

Based on the two long time-series models, average Pacific halibut recruitment is estimated to be higher (70 and 56% for the coastwide and AAF models respectively) during favorable Pacific Decadal Oscillation (PDO) regimes, a widely used indicator of productivity in the north Pacific. Historically, these regimes included positive conditions prior to 1947, poor conditions from 1947-77, positive conditions from 1978-2006, and poor conditions from 2007-13. Annual averages from 2014 through October 2018 have been positive; however, many other environmental indicators, current and temperature patterns have been anomalous relative to historical periods and therefore historical patterns of productivity related to the PDO may not be relevant to the most recent few years. Pacific halibut recruitment estimates show the largest recent cohorts in 1999 and 2005. Cohorts from 2006 through 2010 are estimated to be smaller than those from 1999-2005 which results in a high probability of decline in both the stock and fishery yield as these recruitments become increasingly important to the age range over which much of the harvest and spawning takes place. Based on age data from the 2018 survey, this assessment estimated the 2011 and 2012 year-classes to be similar to those in 2000-04, and higher than estimated in previous assessments, which resulted in a reduction in fishing intensity estimated for 2018 and projected for the next several years.

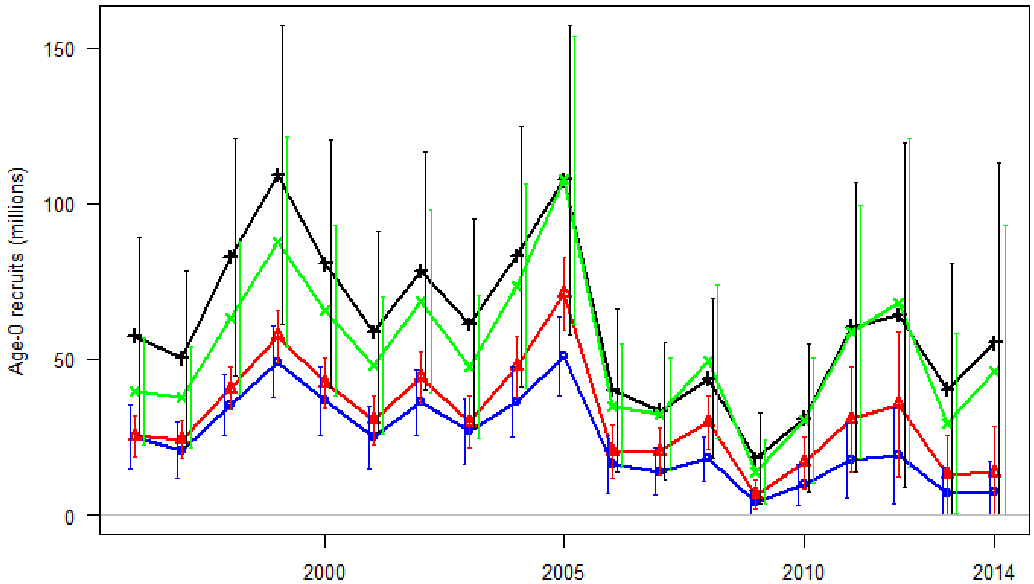

FIGURE 10. Estimated age-0 recruitment trends (1996-2014) based on the four individual models included in the 2018 stock assessment ensemble. Series indicate the maximum likelihood estimates; vertical lines indicate approximate 95% credible intervals.

HARVEST POLICY AND OTHER REFERENCE POINTS

A comparison of the median 2019 ensemble SB to reference levels specified by the IPHC's interim management procedure suggests that the stock is currently at 43% of unfished levels (approximate 95% credible range = 27-63%). The probability that the stock is below the $SB_{30\%}$ level is estimated to be 11%, with less than a 1% chance that the stock is below $SB_{20\%}$ (Table 2). Consistent with the interim management procedure (while improvements are ongoing via the MSE process), estimates of spawning biomass are compared to equilibrium values representing poor recruitment regimes and relatively large size-at-age.

Alternative reference points include the spawning biomass estimated to have occurred at the lowest point in the historical time-series (1974-78), as well as the spawning biomass that would be estimated to occur at present (given recent recruitment and biology) in the absence of fishing (dynamic SB_0; **IPHC-2018-IM094-12**). The two long time-series models provide a comparison with SB levels estimated to have occurred during the historically low stock sizes of the 1970s: the AAF model suggests that recent stock sizes are at 114% of those levels, and the coastwide model at 185%. The estimates of current spawning biomass relative to the dynamic reference point range from 27-43% among the four stock assessment models, with an average value of 37%. Relatively large differences among models reflect both the uncertainty in historical dynamics as well as the importance of spatial patterns in the data and population processes, for which all of the models represent only simple approximations.

TABLE 2. Status summary of Pacific halibut in the IPHC Convention Area at the end of 2018.

Indicators	Values	Trends	Status
Total mortality 2018: Retained mortality 2018: Average mortality 2014-18:	38.74 Mlbs, 17,572 t[1] 31.81 Mlbs, 14,427 t 41.39 Mlbs, 18,772 t	Mortality decreased from 2017 to 2018	**2018 MORTALITY NEAR 100-YEAR LOW**
SPR_{2018}: P(SPR<46%): P(SPR<limit):	49% (28-62%)[2] 34% Limit not specified	Fishing intensity decreased from 2017 to 2018	**FISHING INTENSITY BELOW REFERENCE LEVEL**[3]
SB_{2019} (Mlb): SB_{2019}/SB_0: $P(SB_{2019}<SB_{30})$: $P(SB_{2019}<SB_{20})$:	199 Mlbs (125–287) 43% (27-63%) 11% <1%	SB decreased from 2017 to 2018	**NOT OVERFISHED**[4]
Biological stock distribution	See Table 1 and Figure 6	Distribution stable 2014-18	**REGION 2 ABOVE, REGION 3 BELOW HISTORICAL VALUES**

[1] Weights in this document are reported as 'net' weights, head and guts removed; this is approximately 75% of the round (wet) weight).
[2] Ranges denote approximate 95% credible intervals from the stock assessment ensemble.
[3] Status determined relative to the IPHC's interim reference Spawning Potential Ratio level of 46%.
[4] Status determined relative to the IPHC's interim management procedure biomass limit of $SB_{20\%}$.

MAJOR SOURCES OF UNCERTAINTY

This stock assessment includes uncertainty associated with estimation of model parameters, treatment of the data sources (e.g. short and long time-series), natural mortality (fixed vs. estimated), approach to spatial structure in the data, and other differences among the models included in the ensemble. This results in a broad representation of uncertainty in stock levels and projections relative to analyses for many other species. Although this is an improvement over the use of a single assessment model, there are important sources of uncertainty that are not included.

The 2018 stock assessment results highlight two important sources of current uncertainty: the relative strength of the 2011 and 2012 year-classes, and the scale of the recent biomass. The combination of new data available in 2018 and different responses among the models comprising the stock assessment ensemble have resulted in greater uncertainty in current and projected biomass and fishing intensity than seen in recent years. Specifically, this assessment draws inference regarding the 2011 and 2012 year-classes largely from the age data collected in the 2018 FISS; these estimates will become more certain with additional years of data. The scale of the biomass was positively affected by the FISS expansion data collected in 2018, translated through the space-time modeling, and resulting in much greater precision of the historical time-series. Although all future setline surveys will improve our understanding of stock trends, the expansion in 2019 will complete the coastwide effort and will likely have a greater effect on the historical time-series than subsequent surveys.

As has been the case in previous assessments, there are other uncertainties in the modelling and current understanding of the Pacific halibut resource. The sex-ratio of the commercial catch (not sampled due to the dressing of fish at sea), serves to set the scale of the estimated female abundance in tandem with assumptions regarding natural mortality. It is anticipated that genetic analysis of all Pacific halibut sampled from the commercial landings in 2017 will allow an estimate of the sex-ratio at age from 2017 to be available for the 2019 stock assessment. Although it will likely take several years to generate enough information on the sex ratio of the landings to strongly inform the stock assessment models, this represents a crucial step toward addressing this source of uncertainty for future stock analyses. The uncertainty in the sex-ratio of the historical time-series will remain. The treatment of spatial dynamics and movement rates among Regulatory Areas, which are represented via the coastwide and AAF approaches, has large implications for the current stock trend, as evidenced by the different results among the four models comprising the stock assessment ensemble. Further, movement rates for adult and younger Pacific halibut (roughly ages 0-6, which were not well-represented in the PIT-tagging study), particularly to and from Region 4 (and especially to and from the Eastern Bering Sea), are important and uncertain components in understanding and delineating between the distribution of recruitment among biological Regions, and other factors influencing stock distribution and productivity. Additional important contributors to assessment uncertainty (and potential bias) include factors influencing recruitment, size-at-age, and some estimated components of the fishery removals. The link between Pacific halibut recruitment strengths and environmental conditions remains poorly understood, and although correlation with the Pacific Decadal Oscillation is currently useful, it may not remain so in the future. Therefore, recruitment variability remains a substantial source of uncertainty in current stock estimates due to the lack of mechanistic understanding and the lag between birth year and direct observation in the fishery and survey data (6-10 years). Reduced size-at-age relative to levels observed in the 1970s has been the most important driver of recent decade’s stock trends, but its cause also remains unknown. The historical record suggests that size-at-age changes relatively slowly; therefore, although projection of future values is highly uncertain, near-term values are unlikely to be substantially different than those currently observed. Data suggest that the decreasing trend in size-at-age has slowed and coastwide values have been relatively stable over the last decade. Like most stock assessments, mortality estimates are assumed to be accurate. Therefore uncertainty due to bycatch mortality estimation (observer sampling and representativeness), discard mortality rates, and any other unreported sources of removals in either directed or non-directed fisheries (e.g., whale depredation) could create bias in this assessment. Ongoing research and data collection programs on these topics may help to inform our understanding of these processes in the long-term, but in the near future it appears likely that a high degree of uncertainty in both stock scale and trend will continue to be an integral part of the annual management process.

OUTLOOK

Stock projections were conducted using the integrated results from the stock assessment ensemble, summaries of the 2018 directed fisheries and other sources of mortality. The harvest decision table (Table 3) provides a comparison of the relative risk (in times out of 100), using stock and fishery metrics (rows), against a range of alternative harvest levels for 2019 (columns).

The block of rows entitled “Stock Trend” provides for evaluation of the risks to short-term trend in spawning biomass, independent of all harvest policy calculations. The remaining rows portray risks relative to the spawning biomass reference points (“Stock Status”) and fishery performance relative to the approach identified in the interim management procedure. The alternatives (columns) provided include several coarsely spaced levels of mortality intended for evaluation of stock dynamics including:

- No mortality (useful to evaluate the stock trend due solely to population processes),
- A 10 million pound (~4,500 t) 2019 Total Constant Exploitation Yield (TCEY[3])
- A 50 million pound (~22,700 t) 2019 TCEY
- A 60 million pound (~27,200 t) 2019 TCEY
- The mortality consistent with the “Reference” SPR ($F_{46\%}$) level.
- The mortality consistent with the catch limits set in 2018 (*“status quo”*).

A grid of alternative TCEY values corresponding to SPR values from 40% to 50% (encompassing both the Reference and *status quo* levels is also provided.

For each row of the decision table, the total mortality of all sizes and from all sources, the coastwide TCEY and the associated level of fishing intensity projected for 2019 (median value with the 95% credible interval below; measured via the Spawning Potential Ratio) are reported. Fishing intensity reflects the relative reduction in equilibrium (long-term) spawning biomass per recruit from all sources and sizes of removals, reported as $F_{x\%}$, (where x = the SPR) for comparison to other management processes in both nations where harvest rate targets and limits are commonly reported in these units. Additional alternatives (columns), as well as harvest decision tables created around a differing “reference” SPR can be produced during the IPHCs annual process as needed, such that all 2019 management alternatives under consideration can be compared in terms projected mortality and risk.

The stock is projected to decrease over the period from 2019-21 for all TCEYs greater than 20 million pounds (~9,070 t), corresponding to an SPR of 64% (a 51/100 probability of decrease from 2019 to 2021; Table 3, Figure 11); that result is an indication of near-term projected surplus production. At the *status quo* TCEY (37.2 million lb, ~16,900 t), which corresponds to an estimated SPR of 48% the probability of at least a 5% decrease in stock size increases from 30% (2020) to 79% (2022). At the reference level (and SPR of 46%) those probabilities increase to 37 and 86%. The reference level corresponds to a 87/100 (87%) chance of stock decline through 2020. There is a one third chance (<34/100) that the stock will decline below the threshold reference point (SB30%) in projections for all the levels of fishing intensity up to and SPR of 40% evaluated over three years.

[3] The TCEY corresponds approximately to the mortality comprised of Pacific halibut greater than 26 inches (66 cm) in length.

TABLE 3. Harvest decision table for 2018. 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.

		2019 Alternative	No removals				Status quo		*Reference SPR=46%*									
		Total mortality (M lb)	0.0	11.7	36.1	37.6	39.0	40.4	41.8	43.1	44.3	45.5	46.8	48.3	49.9	51.8	61.8	
		TCEY (M lb)	0.0	10.0	34.3	35.8	37.2	38.6	40.0	41.3	42.5	43.7	45.0	46.5	48.1	50.0	60.0	
		2019 Fishing intensity	$F_{100\%}$	$F_{78\%}$	$F_{50\%}$	$F_{49\%}$	$F_{48\%}$	$F_{47\%}$	$F_{46\%}$	$F_{45\%}$	$F_{44\%}$	$F_{43\%}$	$F_{42\%}$	$F_{41\%}$	$F_{40\%}$	$F_{39\%}$	$F_{34\%}$	
		Fishing intensity interval	--	56-87%	28-64%	27-63%	26-62%	25-61%	25-60%	24-59%	23-59%	23-58%	22-57%	22-56%	21-55%	17-54%	17-49%	
Stock Trend (spawning biomass)	in 2020	is less than 2019	1	3	73	77	81	84	87	90	92	93	95	96	97	98	>99	a
		is 5% less than 2019	<1	<1	22	26	30	34	37	39	41	43	45	48	50	54	78	b
	in 2021	is less than 2019	1	7	87	90	93	94	96	97	98	98	99	99	99	>99	>99	c
		is 5% less than 2019	<1	1	53	57	61	65	69	73	77	80	83	87	90	93	99	d
	in 2022	is less than 2019	1	12	91	93	94	96	97	98	98	99	99	99	>99	>99	>99	e
		is 5% less than 2019	<1	3	71	76	79	83	86	88	90	92	93	95	96	97	>99	f
Stock Status (Spawning biomass)	in 2020	is less than 30%	5	7	16	17	17	18	18	19	19	20	20	21	21	22	25	g
		is less than 20%	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	h
	in 2021	is less than 30%	3	7	23	24	25	25	26	27	27	27	28	29	29	30	33	i
		is less than 20%	<1	<1	1	1	1	1	1	2	2	2	3	3	4	4	10	j
	in 2022	is less than 30%	2	8	28	28	29	29	30	30	31	31	32	33	33	35	41	k
		is less than 20%	<1	<1	4	4	5	6	7	8	9	10	12	13	15	17	24	l
Fishery Trend (TCEY)	in 2020	is less than 2019	0	<1	34	40	45	51	56	60	63	66	69	73	77	81	95	m
		is 10% less than 2019	0	<1	27	29	33	37	42	47	51	54	58	62	66	70	95	n
	in 2021	is less than 2019	0	<1	41	46	51	56	60	64	67	70	73	77	81	85	97	o
		is 10% less than 2019	0	<1	31	35	39	44	49	53	56	59	63	66	71	75	97	p
	in 2022	is less than 2019	0	<1	45	50	54	58	62	66	69	72	76	79	83	87	98	q
		is 10% less than 2019	0	<1	36	40	45	49	53	56	60	62	66	69	73	77	98	r
Fishery Status (Fishing intensity)	in 2019	is above $F_{46\%}$	0	<1	30	35	40	46	50	56	59	62	65	69	72	76	92	s

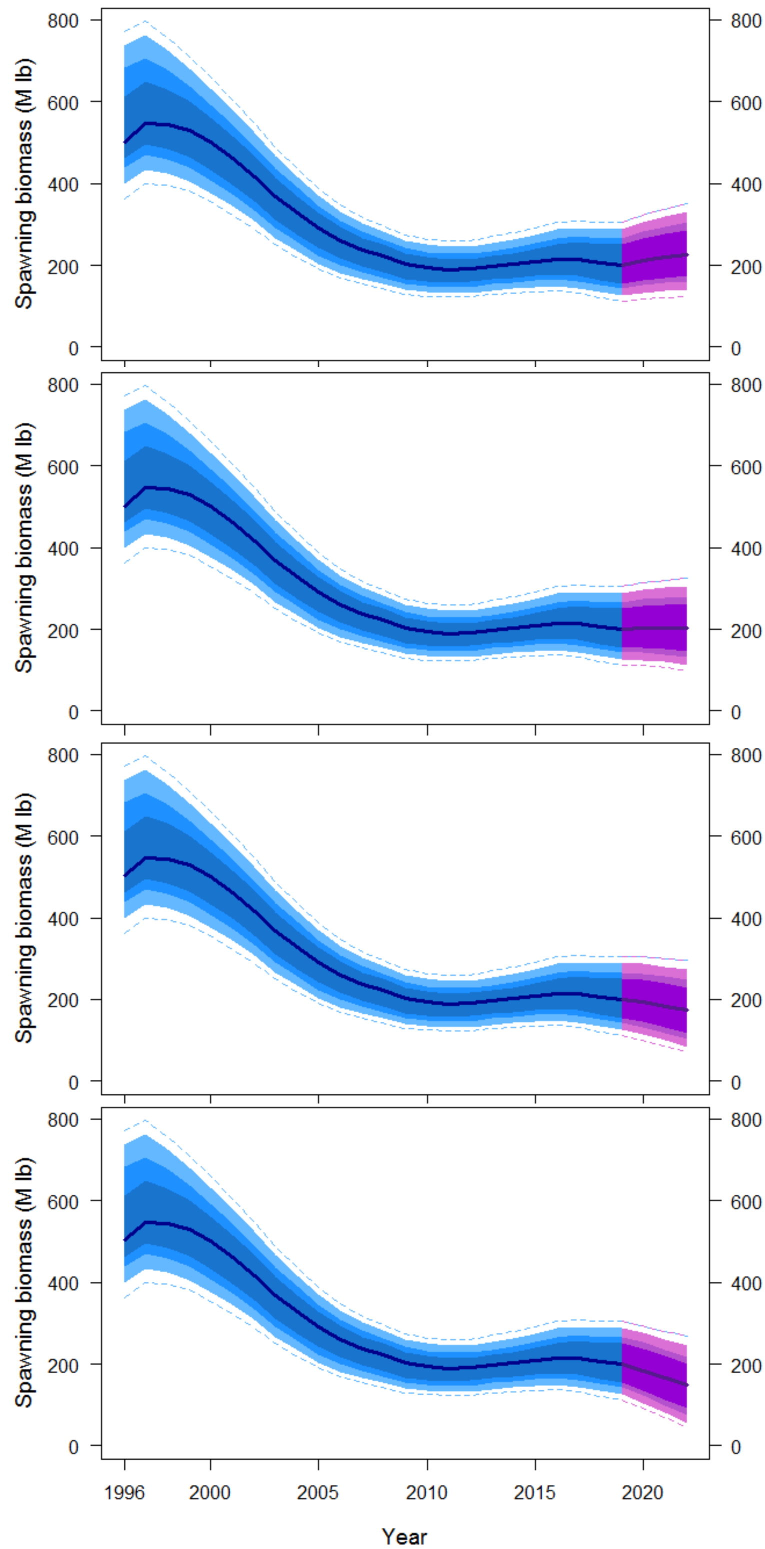

FIGURE 11. Three-year projections of stock trend under alternative levels of mortality: no fishing mortality (upper panel), a TCEY of 20 million lb (~9,070 t; second panel), the Reference SPR=46% (40 million pounds, ~18,150 t; third panel) and a TCEY of 60 million pounds (~27,200 t; lower panel).

Scientific Advice

Sources of mortality: In 2018, total mortality was near the lowest values estimated over the last 100 years (34 million pounds; ~15,420 t), down from 2017. In 2018, 82% of the total mortality was retained compared to 83% in 2017.

Fishing intensity: The 2018 mortality from all sources corresponds to a point estimate of SPR = 49% (there is a 34% chance that fishing intensity exceeded the IPHC's reference level of 46%; Table 2). The Commission does not currently have a coastwide limit fishing intensity reference point.

Stock status (spawning biomass): Current female spawning biomass is estimated to be 199 million pounds (90,300 t), which corresponds to an 11% chance of being below the IPHC threshold (trigger) reference point of $SB_{30\%}$, and less than a 1% chance of being below the IPHC limit reference point of $SB_{20\%}$. Therefore, the stock is considered to be '**not overfished**'. Projections indicate that the reference fishing intensity is likely to result in declining biomass levels in the near future (Figure 11).

Stock distribution: Regional stock distribution has been stable within estimated credibility intervals over the last five years (Figure 6). Region 2 currently represents a greater proportion, and Region 3 a lesser proportion of the coastwide stock than observed in previous decades.

Research Priorities

Research priorities for the stock assessment and related analyses can be delineated into two broad categories: gaps in biological understanding and technical development.

Biological understanding: During the last several years, the IPHC Secretariat has developed a comprehensive five-year research program (**IPHC-2018-IM094-10**). The development of these research priorities has been closely tied to the needs of the stock assessment and harvest strategy policy analyses, such that each of the IPHC's ongoing projects (e.g. determining the sex-ratio of the commercial landings, updating estimates of the maturity schedule for Pacific halibut, better understanding of recruitment processes and stock structure, etc.) will provide data, and hopefully knowledge, about key biological and ecosystem processes that can then be incorporated directly into analyses supporting the management of Pacific halibut.

Technical development: The development of the IPHC's stock assessment, Management Strategy Evaluation (MSE), and harvest strategy policy methods is ongoing, and responds to new developments in the data or analyses necessary each year. New approaches are tested, reported to the IPHC's Scientific Review Board (SRB; generally in June), refined (and reviewed again in October, as needed), and ultimately incorporated in the development of the best scientific information available for the annual management process. During 2019, a full stock assessment analysis, including evaluation of the data processing, modelling methods and ensemble components will undergo independent peer review via the SRB. Technical research priorities for that review include:

1) Maintaining consistency and coordination between MSE, and stock assessment data, modelling and methodology.

2) Continued refinement of the ensemble of models used in the stock assessment.
3) Continued development of weighting approaches for models included in the ensemble, potentially including fit to the survey index of abundance, retrospective, and predictive performance.
4) Exploration of methods for better including uncertainty in discard mortality and bycatch estimates in the assessment (now evaluated only via alternative catch tables or model sensitivity tests) in order to better include these sources uncertainty in the decision table.
5) Bayesian methods for fully integrating parameter uncertainty may provide improved uncertainty estimates within the models contributing to the assessment, and a more natural approach for combining the individual models in the ensemble.

RECOMMENDATION/S

That the Commission:

a) **NOTE** paper IPHC-2018-IM094-08 Rev_1 which provides a summary of data, the stock assessment and the harvest decision table for 2019.