Assessment of the Pacific halibut (*Hippoglossus stenolepis*) stock at the end of 2018

PREPARED BY: IPHC SECRETARIAT (I. STEWART & A. HICKS; 17 DECEMBER 2018)

PURPOSE

To provide the Commission with a detailed report of the 2018 stock assessment analysis.

ABSTRACT

This stock assessment reports the status of the Pacific halibut (*Hippoglossus stenolepis*) resource in the International Pacific Halibut Commission (IPHC) Convention Area at the end of 2018. Coastwide mortality (including all sizes of Pacific halibut) from all sources in 2018 was estimated to be 38.7 million pounds[1] (~17,570 t), down 5% from 2017. In addition to the estimated mortality, the assessment includes data from both fishery dependent and fishery independent sources, as well as auxiliary biological information. The 2018 modelled Fishery-Independent Setline Survey (FISS; see **IPHC-2019-AM095-06** and **IPHC-2019-AM095-07**) detailed a coastwide aggregate Numbers-Per-Unit-Effort (NPUE) 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). The modelled survey Weight-Per-Unit-Effort (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). The FISS sampling associated with the expansion in Region 2 (Regulatory Areas 2A, 2B, and 2C) resulted in revised modelled relative catch-rates in this region compared to the rest of the coast, and reduced the variability about the estimates by approximately 48%. 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 IPHC Regulatory Areas decreasing from the 2017 estimates. A bias correction for each IPHC Regulatory Area based on the last six years of additional logbooks available after the assessment deadline in early November resulted in an estimate of a 13% decrease coastwide and negative trends for all IPHC Regulatory Areas except Area 2A (+5%) and 4B (+2%). In addition to reporting tribal and non-tribal commercial fishery trends in IPHC Regulatory Area 2A separately, catch-rates reported for snap gear and fixed-hook gear are also delineated for comparison. 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. Trends over the last five years indicate that population distribution (measured via the modelled biomass of all Pacific halibut captured on the FISS) has been relatively stable among Biological Regions, 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.

[1] All weights in the document are ‘net’ weights; head-off and entrails removed approximately 75% of round weight.

This stock assessment consists of four equally-weighted models, two long time-series models, and two short time-series models either using data sets by geographical region, or aggregating all data series into coastwide summaries; these models are structurally unchanged since the most recent detailed independent scientific review in 2015. Results are based on the approximate probability distributions derived from the ensemble of models, thereby incorporating the uncertainty within each model as well as the uncertainty among models. The results of the 2018 stock assessment indicate that the Pacific halibut stock declined continuously from the late 1990s to around 2011. 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). 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 1% larger the estimate from the 2017 stock assessment. However, the uncertainty is larger as the effects of the revised time-series in Biological Region 2 influenced each of the individual models differently, and even though it reduced uncertainty in the dataset itself, the revision resulted in a greater difference in the magnitude of the terminal year's estimated spawning biomass between models. 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.

A comparison of the median 2019 ensemble SB estimate 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 $SB_{20\%}$. Consistent with the interim management procedure (while improvements are ongoing via the Management Strategy Evaluation process; see **IPHC-2019-AM095-12**), estimates of spawning biomass are compared to equilibrium values representing poor recruitment regimes and relatively large size-at-age. Stock projections were conducted using the integrated results from the stock assessment ensemble, details of IPHC Regulatory Area-specific catch sharing plans and estimates of mortality from the 2018 directed fisheries and other sources of mortality where these values are projected for 2019. 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 a Spawning Potential Ratio (SPR) of 64%. At the reference level (SPR of 46% and a TCEY of 40 Mlbs or 18,140 t) the probability of at least a 5% decrease in stock size increases from 37% (2020) to 86% (2022). There is a one third chance (<34/100) that the stock will decline below the threshold reference point ($SB_{30\%}$) in projections for all the levels of fishing intensity up to an SPR of 40% evaluated over three years.

Retrospective analyses and sensitivity analyses exploring current sources of uncertainty are also included in this document.

INTRODUCTION

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[2] are set each year by the Commission. The stock assessment provides a brief summary of recently collected data; a more detailed treatment of data sources included in the assessment and used for other analyses supporting harvest policy calculations is provided in **IPHC-2019-AM095-08**. Results include current model estimates of stock size and trend reflecting all available data. Specific management information is summarized via a decision table reporting the estimated risks associated with alternative management actions. Mortality tables projecting detailed summaries for fisheries in each IPHC Regulatory Area (and reference levels indicated by the IPHC's interim management procedure) can be explored via the IPHC's mortality projection tool (https://iphc.int/data/projection-tool).

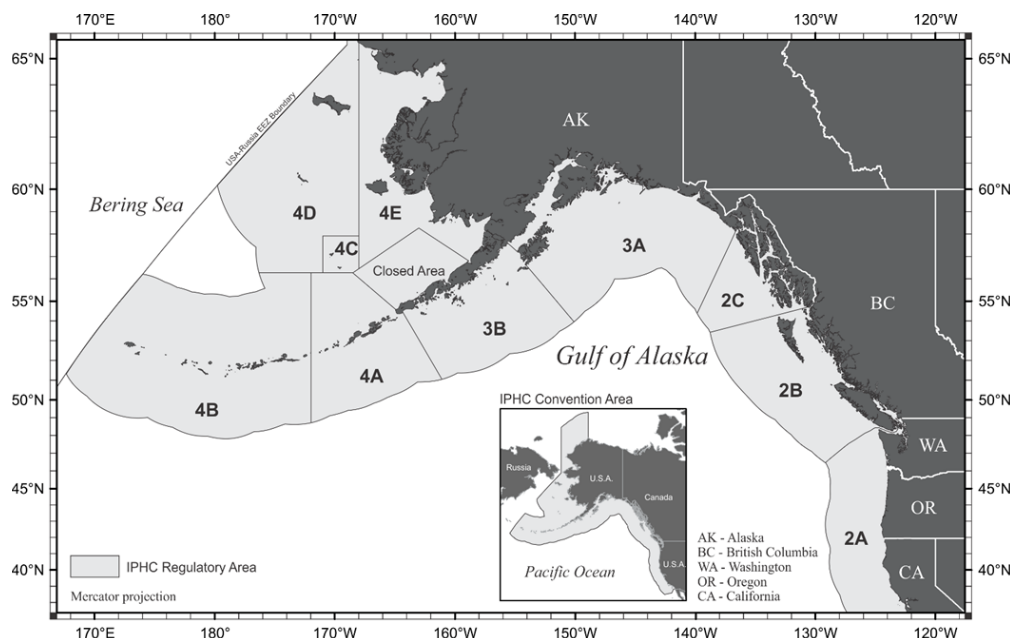

FIGURE 1. IPHC Regulatory Areas and the Pacific halibut geographical range within the territorial waters of Canada and the United States of America.

DATA SOURCES

Each year, the data sources used to support this assessment are updated to include newly available information, and refined to reflect the most current and accurate information available to the IPHC. Major reprocessing and development of supplementary data sources was conducted in 2013 and 2015 (Stewart 2014, 2016, Stewart and Martell 2016). In 2016, a model-based estimator was introduced for describing the trends in the IPHC fishery-independent setline survey (FISS); this analysis has been updated each year with all available information including

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

the FISS expansion in Biological Region 2 in 2018 (**IPHC-2019-AM095-07**). 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, or include projections for the remainder of the year. These include commercial fishery WPUE, commercial fishery age composition data, and 2018 mortality estimates for all fisheries still operating after 9 November. All preliminary data series in this analysis will be fully updated as part of the 2019 stock assessment.

Data are initially compiled by IPHC Regulatory Area and then aggregated to four Biological Regions: Region 2 (2A, 2B, and 2C), Region 3 (3A, 3B), Region 4 (4A, 4CDE) and Region 4B, and to the coastwide level. In addition to the mortality estimates (including all sizes of Pacific halibut), the assessment includes data from both fishery dependent and fishery independent sources, as well as auxiliary biological information. Primary sources of information for this assessment include modelled indices of abundance from the annual FISS (**IPHC-2019-AM095-06** and **IPHC-2019-AM095-07**) and commercial Catch-Per-Unit-Effort (numbers and weight), and biological summaries (length-, weight-, and age-composition data). In aggregate, the historical time series of data available for this assessment represents a considerable resource for analysis. The range of relative data quality and geographical scope are also considerable, with the most complete information available only in recent decades (Figure 2). A detailed summary of input data used in this stock assessment can be found in **IPHC-2019-AM095-08**.

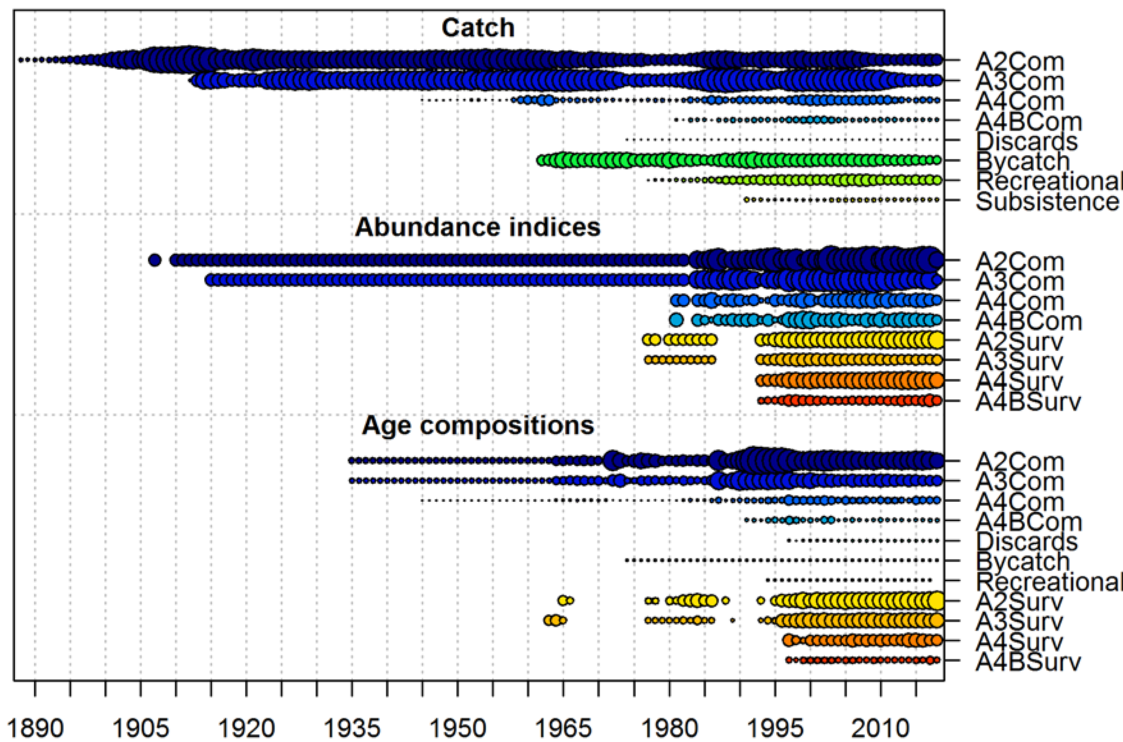

FIGURE 2. Overview of data sources. Circle areas are proportional to magnitude (catches) or the relative precision of the data (indices of abundance and age composition data).

Briefly, 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). 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. 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)[3], 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).

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). 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). 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%. 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 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 (**IPHC-2019-AM095-08**).

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. Trends over the last five years indicate that population distribution (measured via the modelled biomass of all Pacific halibut captured on the FISS) has been relatively stable among Biological Regions, 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 (**IPHC-2019-AM095-08**). 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.

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

STOCK ASSESSMENT

Creating robust, stable, and well-performing stock assessment models for the Pacific halibut stock has historically proven to be problematic due to the highly dynamic nature of the biology, distribution, and fisheries (Stewart and Martell 2014). The stock assessment for Pacific halibut has evolved through many different modeling approaches over the last 30 years (Clark 2003). These changes have reflected improvements in fisheries analysis methods, changes in model assumptions, and responses to recurrent retrospective biases and other lack-of-fit metrics (Stewart and Martell 2014). Although recent modelling efforts have created some new alternatives, no single model satisfactorily approximates all aspects of the available data and scientific understanding. Building on simpler approaches in 2012 and 2013, in 2014, an ensemble of four stock assessment models representing a two-way cross of short vs. long time series', and aggregated coastwide vs. Areas-As-Fleets (AAF) models was used to explore the range of plausible current stock estimates. AAF models are commonly applied when biological differences among areas or sampling programs make coastwide summary of data sources problematic (Waterhouse et al. 2014). AAF models continue to treat the population dynamics as a single aggregate stock, but fit to each of the spatial datasets individually, allowing for differences in selectivity and catchability of the fishery and survey among regions. In addition, the AAF models more easily accommodate temporal and spatial trends in where and how data have been collected, and fishery catches have occurred. This is achieved through explicitly, accounting for missing information in some years, rather than making assumptions to expand incomplete observations to the coastwide level. These four models are structurally unchanged since the most recent detailed scientific review in 2015 (Stewart and Martell 2016). Each of these models (and many alternatives explored during development) has shown a similar historical pattern: a stock declining from the late 1990s, with several years of relative stability at the end of the time-series.

The ensemble approach recognizes that there is no "perfect" assessment model, and that a robust risk assessment can be best achieved via the inclusion of multiple models in the estimation of management quantities and the uncertainty about these quantities (Stewart and Hicks 2018b, Stewart and Martell 2015). This stock assessment is based on the approximate probability distributions derived from an ensemble of models, thereby incorporating the uncertainty within each model as well as the uncertainty among models. This approach reduces 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.

Consistent with the analyses from 2015-17, this stock assessment is implemented using the generalized software stock synthesis (Methot Jr and Wetzel 2013), a widely used modeling platform developed at the National Marine Fisheries Service. This combination of models included a broad suite of structural and parameter 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), fishery and survey selectivity (by region in the AAF models) and other model parameters. These sources of uncertainty have historically been very important to the understanding of the stock, as well as the annual assessment results (Clark and Hare 2006, Clark et al. 1999, Stewart and Martell 2016). The benefits of the long time-series models include historical perspective on recent trends and biomass levels; however, these benefits come at a computational and complexity cost. The short time-series models make fewer assumptions about the properties of less comprehensive historical data, but they suffer from much less information in the short data series as well as little context for current dynamics.

Each of the models in the ensemble was equally weighted, and differences in uncertainty within models propagated in the integration of results. In the future, it may be desirable to develop a method for weighting models based on the lack-of-fit to key data sources, retrospective patterns within models, as well as consistency of the results with biological understanding. Evaluation of alternative weighting approaches was presented to the IPHC Scientific Review Board (SRB) in 2015, 2016 and 2017 (Stewart 2017), but did not suggest a change to the equal weights that have been applied; therefore, that assumption is retained. Planned independent Scientific Review in June 2019 (SRB014) will explore the structural assumptions of each of these models, the methods used to integrate them, and the weighting approach. Additional models or variations of existing models may be evaluated for potential inclusion into the ensemble at that time or in future years. In this manner, the ensemble approach can be transparently improved in the future as additional approaches and refinements become available.

COMPARISON WITH PREVIOUS ASSESSMENTS

Comparison of this year's results with previous stock assessments indicates that the estimates of spawning biomass from the 2018 ensemble remain consistent with those from 2012-17. Each of the previous terminal assessment values lie inside the predicted 50% interval of the current ensemble (Figure 3). Models prior to 2012, which had shown a problematic retrospective pattern, suggested terminal stock trends and sizes in the mid-2000s that are no longer considered plausible. Point estimates for the 2018 SB from the 2017 ensemble (Stewart and Hicks 2018a) were slightly lower than the current results, but statistically very similar given the degree of uncertainty (Table 1). 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. The level of fishing intensity (measured via the Spawning Potential Ratio, SPR) projected for 2018 was $F_{41\%}$; however, in retrospect (based on revised recent year-class strengths and actual mortality) a lower level of fishing intensity ($F_{48\%}$) is estimated in this year's assessment (Table 1).

TABLE 1. Comparison of 2018 median ensemble beginning-of-year spawning biomass (Mlb) and Spawning Potential Ratio estimates from the 2017 and current assessments (with approximate 95% credible intervals).

Quantity	2017 Assessment	2018 Assessment
2018 Spawning biomass	202 (148-256)	205 (134-288)
2018 SPR	41% (30-60%)	49% (28-62%)

BIOMASS, RECRUITMENT, AND REFERENCE POINT RESULTS

Ensemble

The results of the 2018 stock assessment indicate that the Pacific halibut stock declined continuously from the late 1990s to around 2011 (Figure 3, Table 2). 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 4). The differences among the individual models contributing to the ensemble are most pronounced prior to the early 2000s (Figure 5);

however, current stock size estimates (at the beginning of 2019) also differ substantially among the four models (Figure 6). The differences in both scale and recent trend reflect the structural assumptions, e.g., higher natural mortality estimated in the long coastwide model and dome-shaped selectivity for Regions 2 and 3 in the AAF models. Differences are also apparent in the recent recruitment estimates, which suggest larger recruitments in 1999 and 2005 than in other recent years (Figure 7, Table 2). All of these recent recruitments are much lower than the 1987 cohort, and in the two long time-series models they are at or below those in the late 1970s and early 1980s (Figure 8). 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. Of particular note for short-term trends in fishery yield as well as spawning biomass, the Pacific halibut born in 2006 will be 50% mature in 2018, and will be fully available to the directed fisheries. The differing effects of these reduced recruitments on fishery yield are illustrated in the estimated declines in age-8+ biomass, which start earlier and are more pronounced than those seen for spawning biomass (Figure 9, Table 2). Recruitment estimates after 2012 remain poorly informed by information from the fishery and survey data, and are therefore highly uncertain. In addition to recruitment trends, observed decreases in size-at-age have also been an important contributor to recent stock declines.

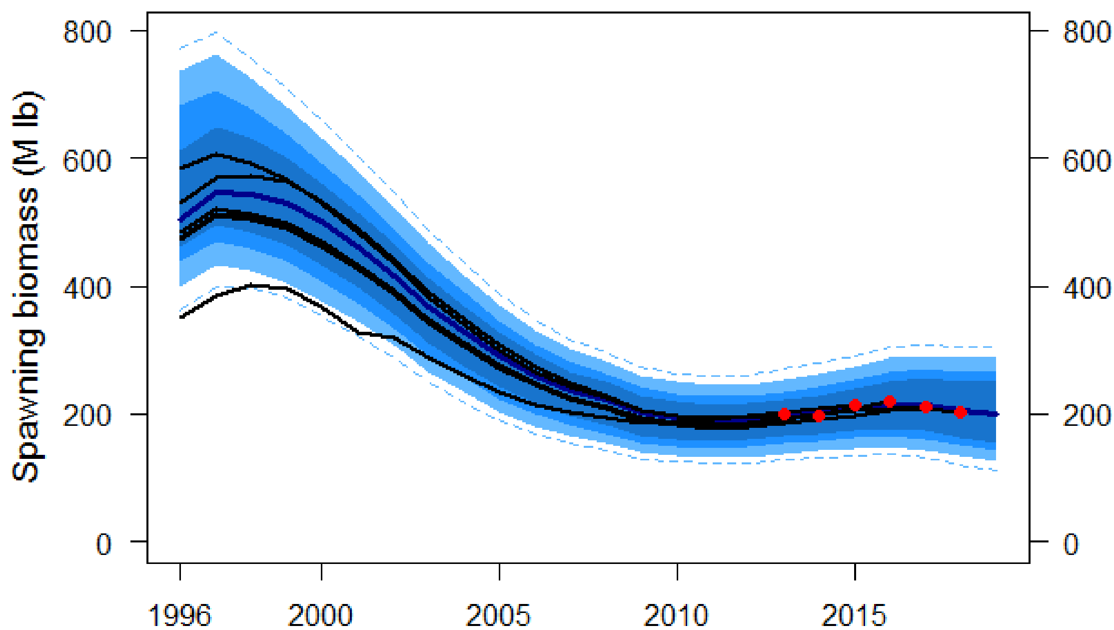

FIGURE 3. Retrospective comparison among recent IPHC stock assessments. Black lines indicate estimates of spawning biomass from assessments conducted from 2012-2017 with the terminal estimate shown as a point, the shaded distribution denotes the 2018 ensemble: the dark blue line indicates the median (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.

TABLE 2. Estimated recent median spawning biomass (SB; millions lbs) and fishing intensity (smaller values indicate higher fishing intensity) with approximate 95% credibility intervals, and age-0 recruitment (millions) and age-8+ biomass (millions lbs) from the individual models (CW=coastwide, AAF=Areas-As-Fleets) comprising the ensemble.

			Fishing	Fishing	Recruitment				Age-8+ biomass			
Year	SB	SB interval	intensity ($F_{XX\%}$)	intensity interval	CW Long	CW Short	AAF Long	AAF Short	CW Long	CW Short	AAF Long	AAF Short
1996	503	398-737	51%	37-66%	57.5	24.9	39.6	25.3	1,809	1,230	1,805	1,688
1997	546	432-762	45%	32-62%	50.2	20.8	37.7	24.2	1,859	1,292	1,874	1,736
1998	543	424-727	43%	30-61%	82.8	35.3	63.3	40.5	1,776	1,236	1,794	1,643
1999	530	406-681	41%	29-60%	109.2	49.2	87.7	57.4	1,638	1,146	1,661	1,507
2000	500	377-633	41%	29-60%	80.6	36.5	65.7	42.5	1,487	1,045	1,520	1,376
2001	461	344-580	38%	28-58%	58.8	24.8	48.1	30.5	1,314	928	1,355	1,224
2002	416	307-525	34%	26-55%	78.5	36.1	68.4	44.3	1,252	877	1,282	1,153
2003	368	266-467	31%	23-52%	61.3	26.7	47.5	29.7	1,189	824	1,214	1,083
2004	327	233-417	28%	22-49%	83.2	36.3	73.4	47.5	1,082	751	1,107	986
2005	290	204-370	26%	21-48%	107.6	50.9	107.5	71.0	970	669	1,002	889
2006	260	181-332	26%	21-48%	40.1	16.1	35.0	20.2	915	625	950	835
2007	238	165-302	26%	21-48%	33.5	13.8	32.4	20.4	909	616	955	828
2008	222	154-284	26%	21-48%	43.8	17.9	49.3	29.8	864	586	925	801
2009	202	140-260	27%	21-49%	18.0	4.1	13.6	6.5	783	528	853	737
2010	194	134-250	27%	21-49%	31.1	9.6	30.2	16.7	749	508	835	719
2011	190	132-246	33%	25-53%	60.4	17.5	58.9	30.7	707	481	798	686
2012	190	133-247	38%	27-57%	64.1	19.1	68.1	35.5	705	481	811	696
2013	196	139-254	41%	29-58%	40.4	6.8	29.6	12.8	744	517	889	760
2014	202	142-263	46%	31-61%	55.2	7.3	46.2	13.6	700	493	856	734
2015	208	145-275	47%	31-61%	NA	NA	NA	NA	653	469	825	715
2016	215	149-288	48%	31-62%	NA	NA	NA	NA	632	458	833	722
2017	213	144-292	48%	29-61%	NA	NA	NA	NA	569	413	771	672
2018	205	134-288	49%	28-62%	NA	NA	NA	NA	526	374	735	638
2019	199	125-287	NA	37-66%	NA	NA	NA	NA	536	360	761	644

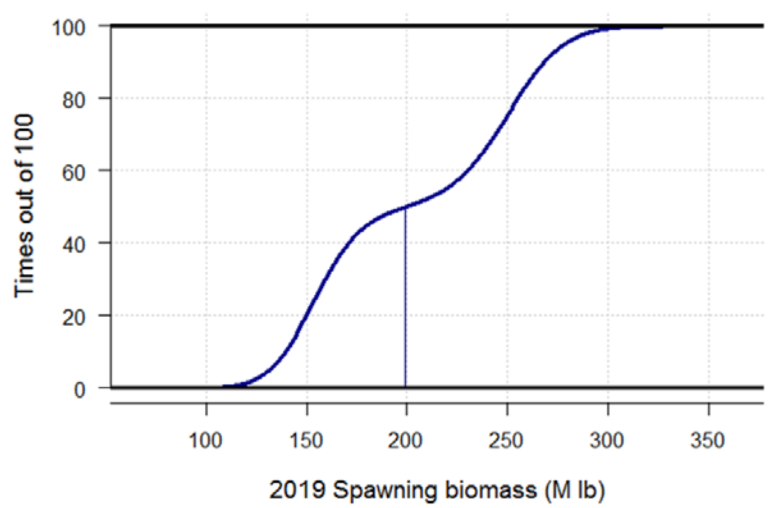

FIGURE 4. Cumulative distribution of the estimated spawning biomass at the beginning of 2019. Curve represents the estimated probability that the biomass is less than or equal to the value on the x-axis; vertical line represents the median (199 million pounds; ~90,300 t).

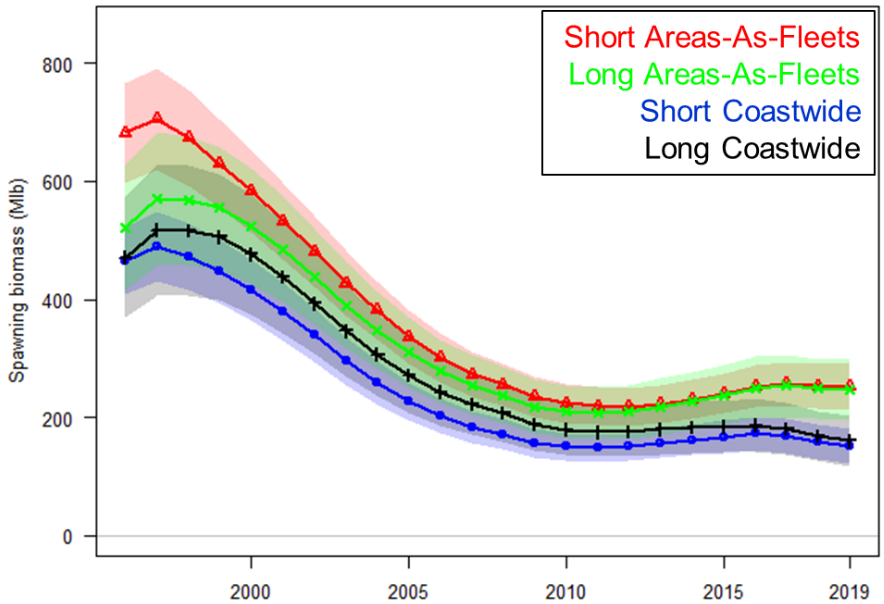

FIGURE 5. Estimated spawning biomass trends (1996-2019) based on the four individual models included in the 2018 stock assessment ensemble. Solid lines indicate the maximum likelihood estimates; shaded intervals indicate approximate 95% credible intervals.

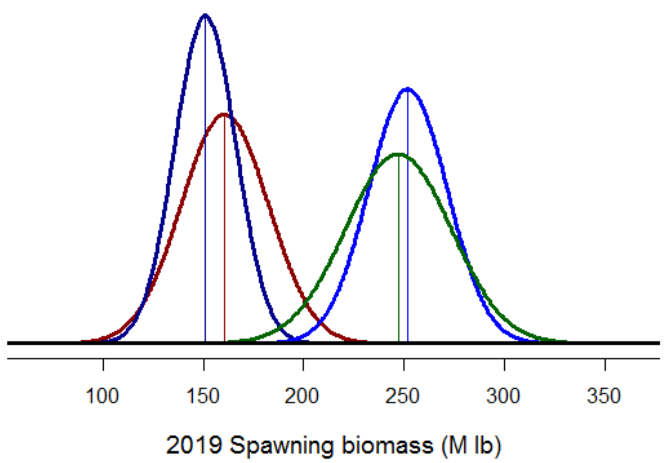

FIGURE 6. Distribution of individual model estimates for the 2019 spawning biomass. Vertical lines indicate the median values.

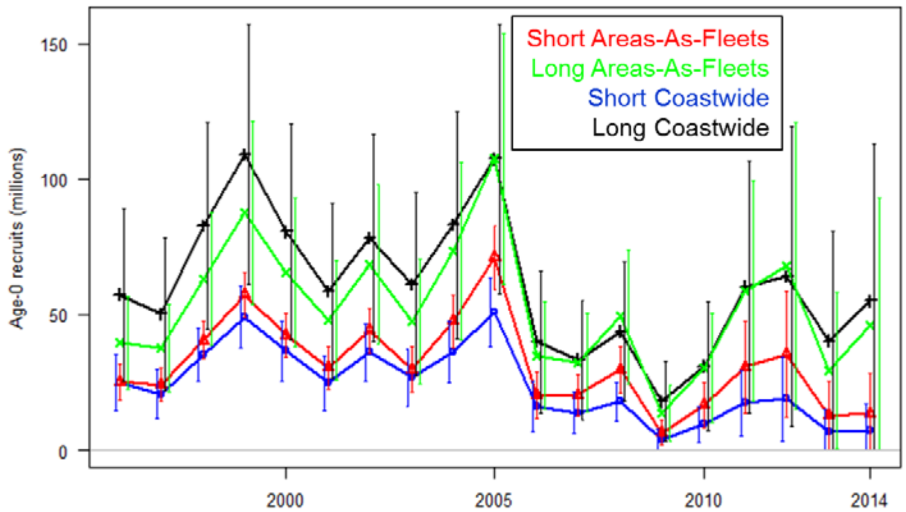

FIGURE 7. Estimated age-0 recruitment trends (1996-2014) based on the four individual models included in the 2018 stock assessment ensemble. Series indicate the maximum likelihood estimates; vertical lines indicate approximate 95% credible intervals.

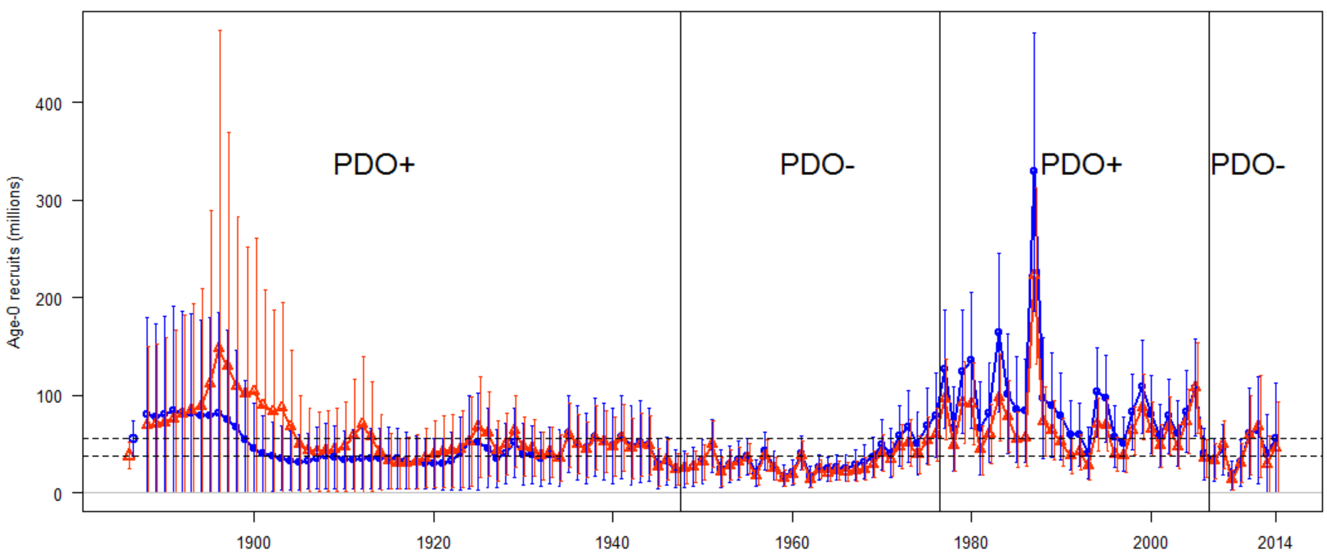

FIGURE 8. Trend in historical recruitment strengths (by birth year) estimated by the two long time-series models, including the effects of the Pacific Decadal Oscillation (PDO) regimes.

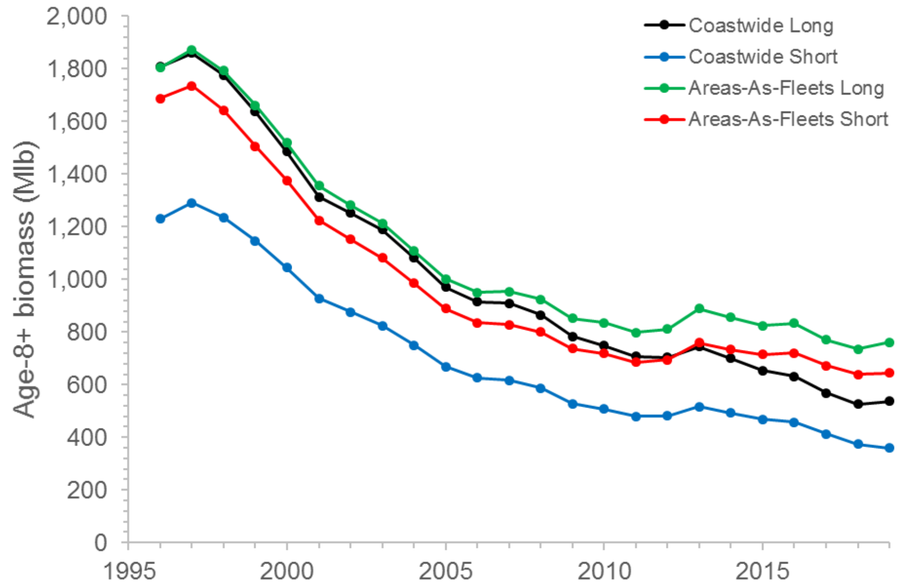

FIGURE 9. Estimated age-8+ biomass trends (1996-2019) based on the four individual models included in the 2018 stock assessment ensemble. Credible intervals for these estimates are not currently available but are likely larger than those observed for spawning biomass.

Ecosystem conditions

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.

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%; Figure 10). 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 $SB_{20\%}$. 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-2019-AM095-12**). 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%. All sources of estimated mortality for 2018 correspond to a fishing intensity point estimate of $F_{49\%}$ (Table 2, Figure 11). Harvest levels of this magnitude are generally at or below target rates for many similar stocks. The 95% interval of this distribution is considerable ($F_{62\%}$-$F_{28\%}$), and slightly irregular, reflecting the different distributions estimated within each of the individual models. The recent time-series shows that the 2018 estimate corresponds to slightly lower fishing intensity than 2014-2016, with the most recent five years considerably below values from 2000-2013 (Figure 12).

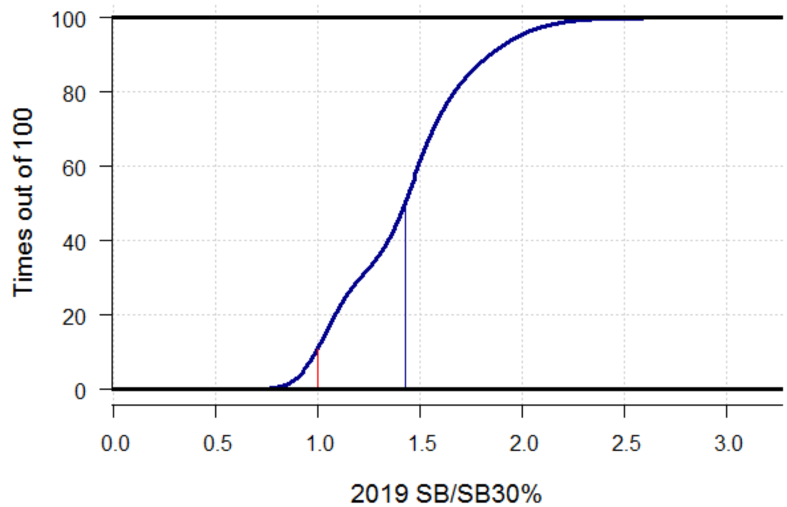

FIGURE 10. Cumulative distribution of 2019 ensemble spawning biomass estimates relative to the $SB_{30\%}$ reference point. Curve represents the estimated probability that the biomass is less than or equal to the value on the x-axis. Vertical lines denote the values corresponding to the fishery threshold in the IPHC's harvest policy (red; $SB_{30\%}$), and the median (blue; 43%).

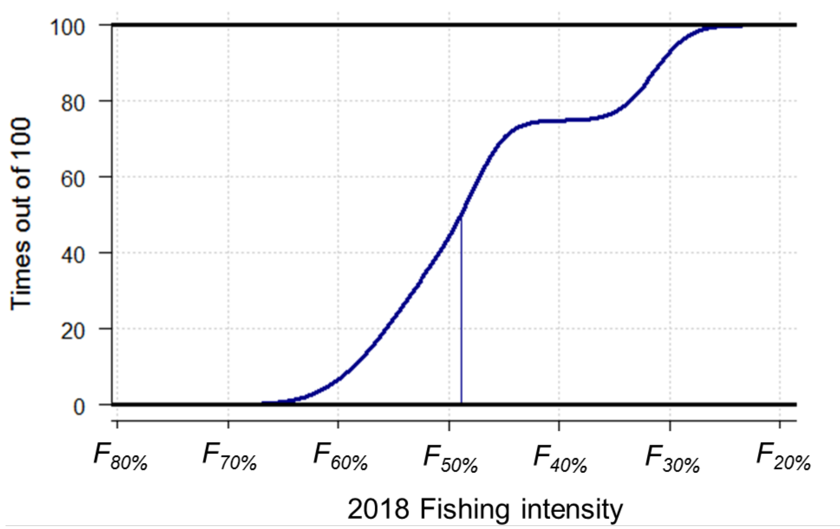

FIGURE 11. Cumulative distribution of the estimated fishing intensity (based on the Spawning Potential Ratio) estimated to have occurred in 2018. Curve represents the estimated probability that the fishing intensity is less than or equal to the value on the x-axis. Vertical line indicates the median value ($F_{49\%}$).

Long time-series models

The two long time-series models provided different perceptions of current vs. historical stock sizes (Figure 11). The two long time-series models also 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%. 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. Recent differences are likely attributable to the separation of signals from each region (particularly Region 2, with the longest time-series of data), and allowance for different properties in each region's fishery and survey. Historical differences appear to be due to the differing assumptions regarding connectivity between Regions 2-3 and Regions 4-4B during the early part of the 1900s when there are no data available from Regions 4-4B (Stewart and Martell 2016).

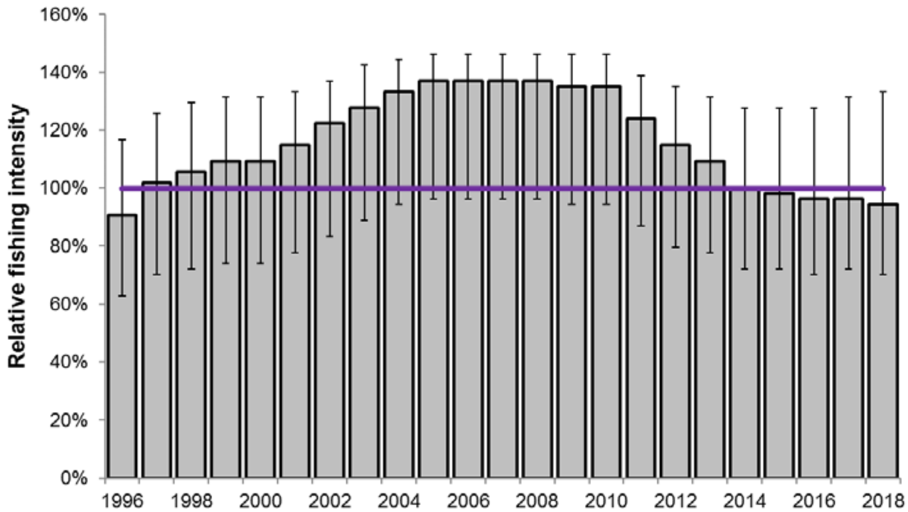

FIGURE 12. Recent estimated fishing intensity (1996-2018; based on the Spawning Potential Ratio) relative to the SPR=46% reference level (horizontal line). Vertical lines indicate approximate credible intervals from the stock assessment ensemble.

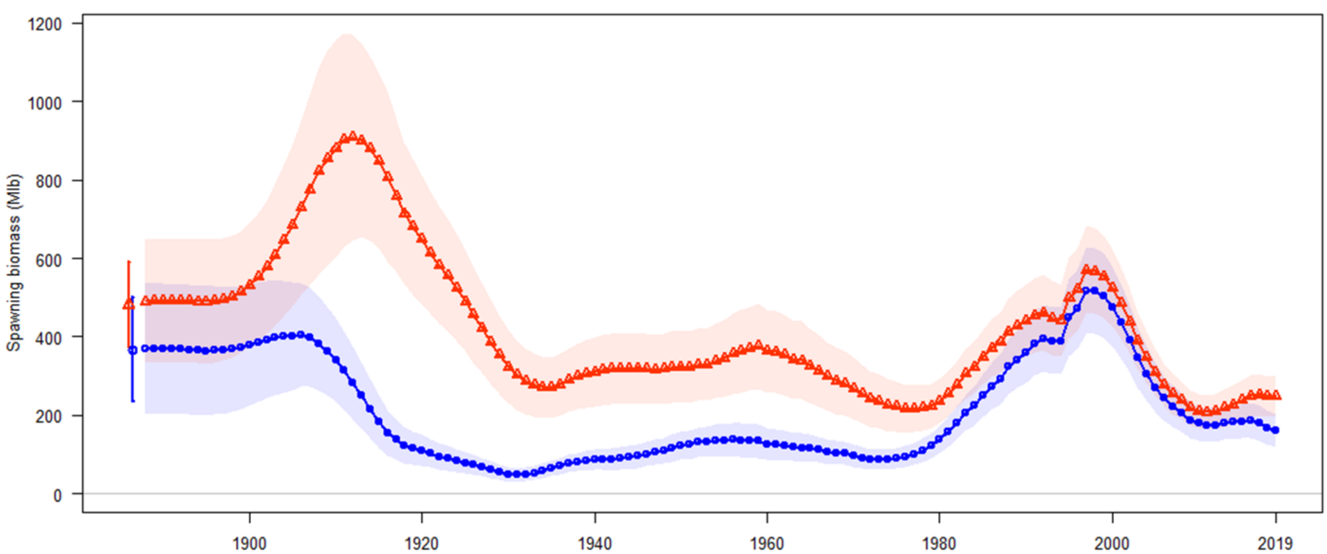

FIGURE 13. Spawning biomass estimates from the two long time-series models. Shaded region indicates the approximate 95% within-model credible interval. The red (upper) series is the Areas-As-Fleets model and the blue (lower) series is the coastwide model.

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 survey time-series. Although all future 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.

This stock assessment contains a broad representation of uncertainty in stock levels when compared to analyses for many other species. This is due to the inclusion of both within-model (parameter or estimation uncertainty) and among-model (structural) uncertainty. The distribution for spawning biomass estimated at the beginning of 2019 (Table 2) reflects this, such that the small differences between the estimate from the 2018 and recent assessments (Table 1, Figure 2) are not statistically significant.

Since 2012, natural mortality has been an important source of uncertainty that is included in the stock assessment. In 2012, three fixed levels were used to bracket the plausible range of values. In 2013, the three models contributing to the ensemble included both fixed and estimated values of natural mortality. In the current ensemble, the models again span both fixed (0.15/year for female Pacific halibut) and estimated values. The female value estimated in the long AAF model (0.18) differs substantially from the value estimated in the coastwide model (0.22). This discrepancy contributes to the difference in scale and productivity for the two models, but is not easily reconciled at present. Although this uncertainty is directly incorporated into the ensemble results, it remains an avenue for future investigation.

Future expansion of the ensemble approach will continue to improve uncertainty estimates, and create assessment results that are robust to changes in individual models, data sets, and other sources of historical changes in stock assessment results from year to year.

SENSITIVITY AND RETROSPECTIVE ANALYSES

A wide range of sensitivity analyses were conducted during the development of the 2015 stock assessment (Stewart and Martell 2016). These efforts form the primary basis for the identification of important sources of uncertainty outlined above. The most important contributors to estimates of both population trend and scale included: the sex-ratio of the commercial catch, the treatment of historical selectivity in the long time-series models, and natural mortality. Several sensitivity analyses were investigated in the 2017 stock assessment in order to update and illustrate their importance, particularly with regard to the IPHC's research program (Stewart and Hicks 2018a). Those sensitivities included trends in spawning output (due to skip spawning or changes in maturity schedules), sex ratio of the commercial landings, and the effects of unobserved mortality of spawning biomass scale and trends. The results of those analyses illustrated the importance of ongoing research into factors influencing reproductive biology and success for Pacific halibut, the genetic analysis of commercial sex-ratios at age as well as whale depredation and discard mortality rates (**IPHC-2019-AM095-14**).

For this year's stock assessment the focus of sensitivity analyses was in better understanding the effects of data collected during 2018. During development of the stock assessment two sources of information were identified as particularly important to the results: the survey expansion conducted in Biological Region 2 in 2018, and the age data collected during 2018 coastwide. The 2018 FISS expansion (**IPHC-2019-AM095-06**) sampled portions of Regulatory Areas 2B and 2C that had never before been included in the annual survey design. Time series from previous year's survey modelling were much more uncertain than those produced for this assessment (**IPHC-2019-AM095-07**). Adding this new and more precise information to the stock assessment models produced slightly less pessimistic results toward the end of the time-series for the two Areas-As-Fleets models. This difference among the four models is due to the treatment of data sources in a less aggregated manner than in the Areas-As-Fleets models. For this sensitivity, after all other data sources had been included, the modelled survey time-series was revised to exclude the new information (expansion stations) from Region 2. This resulted in trends much more similar to the 2017 stock assessment (Figure 14), and a closer correspondence among the four models for the last several years of the estimated time-series than observed with all data included (Figure 5).

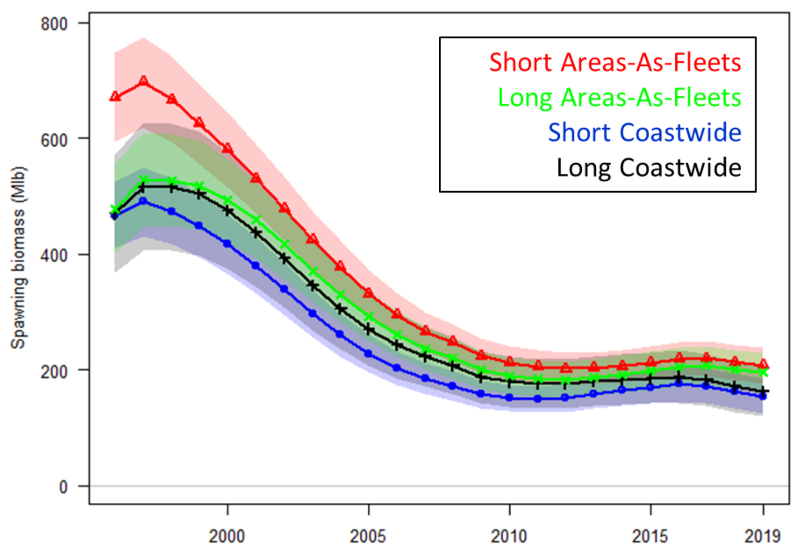

FIGURE 14. Spawning biomass estimates from a sensitivity analysis excluding the 2018 survey expansion data collected in Biological Region 2 from each of the four individual stock assessment models. Shaded regions indicate approximate 95% within-model credible intervals.

The second notable change in assessment results due to newly available data was the increased estimates of recruitment in 2011 and 2012 relative to 2006-10 (Figure 7). To explore whether this change in recruitment was a function of updated productivity estimates in the models or whether it was in fact informed by new data directly, a second sensitivity was conducted that excluded the age information from 2018, but retained all other new trend and mortality data. This sensitivity estimated much lower recruitment strengths for 2011-12 (Figure 15). The sensitivity to these new data serves to underscore the importance of next year's observations which could enhance or contradict those from 2018.

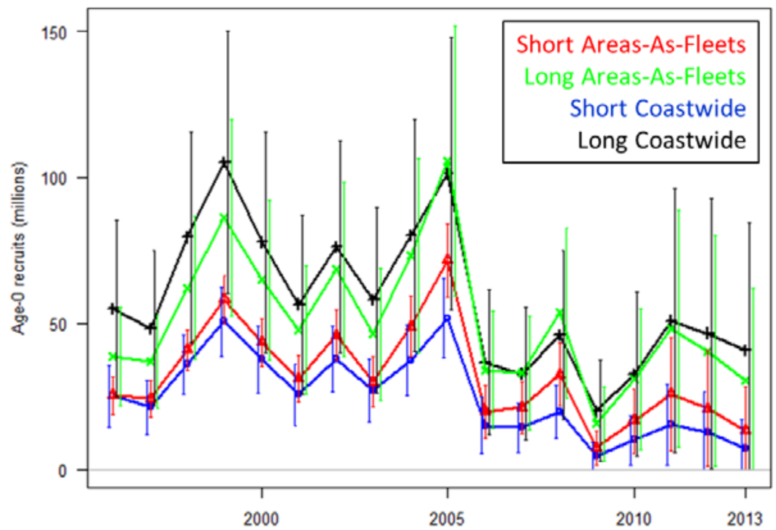

FIGURE 15. Age-0 recruitment estimates from a sensitivity analysis removing the 2018 age data (survey and commercial fishery) from each of the four individual models comprising the 2018 ensemble. Vertical lines indicate approximate 95% within-model credible intervals.

A retrospective analysis was performed for each of the individual models contributing to this assessment. This exercise consists of sequentially removing the terminal year's data and rerunning the assessment model for a total of five iterations (five years of data removed from the models) in order to investigate how that information changed the time-series estimates. Both long time-series models showed little pattern in the most recent years, with all five terminal estimates inside the credibility interval from the 2018 results. Both models had some slightly higher estimates as additional data were removed; however, they also showed similar trends regardless of the data included (Figure 16). The short time-series models, as they have in recent assessments, showed similar but slightly larger retrospective behavior, with terminal estimates inside the credibility intervals for one to three of the five years examined (Figure 17). This is not unexpected for short time-series models where there is a greater proportion of the total available information contained in each year's data. This is particularly true when recruitment strengths are updated away from the central tendency, either in a positive of negative direction.

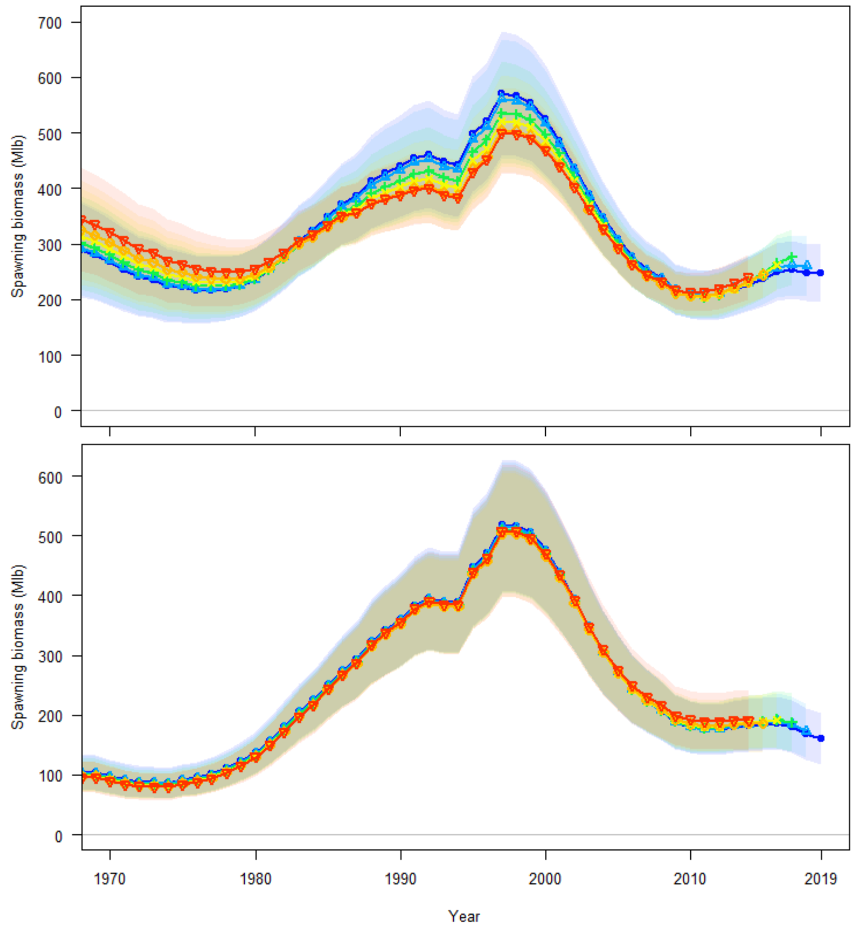

FIGURE 16. Results of the retrospective analysis on spawning biomass estimates using the Areas-As-Fleets long (upper panel) and coastwide long (lower panel) time-series models and sequentially removing one year of data for five years. Shaded regions indicate within-model 95% credibility intervals.

FORECASTS AND DECISION TABLE

Stock projections were conducted using the integrated results from the stock assessment ensemble, estimates of mortality from the 2018 fisheries (directed and non-target). The harvest decision table (Table 3) provides a comparison of the relative risk (in times out of 100), based on a range of stock and fishery metrics (rows), against an array of alternative harvest levels for 2019 (columns). This table differs from similarly reported metrics from the MSE in that it represents a tactical decision-making tool, reflecting the best estimates of trends and harvest levels for the next one to three years. In contrast, the risk metrics reported as part of the MSE (**IPHC-2019-AM095-12**) represent strategic information about the behavior of the Pacific halibut stock over a wide range of biological and environmental conditions. Thus, the two sets of results are complimentary, informing the current decision for 2019 harvest levels (assessment decision table) and informing the strategic management procedure choices most likely to optimize stock and fishery objectives (MSE metrics).

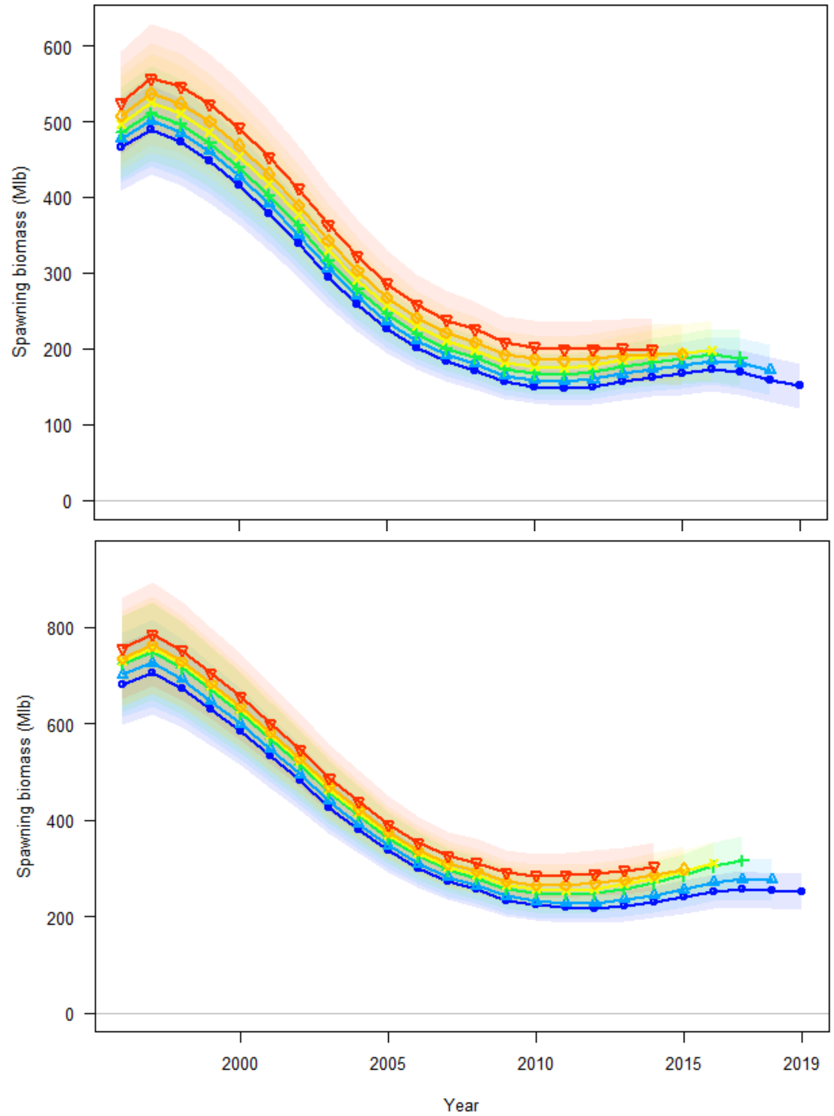

FIGURE 17. Results of the retrospective analysis on spawning biomass estimates using the coastwide short (upper panel) and Areas-As-Fleets short (lower panel) time-series models and sequentially removing one year of data for five years. Shaded regions indicate within-model 95% credibility intervals.

The harvest decision table rows are divided into four sections:

1) 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.

2) The second block of rows reports the risks relative to the spawning biomass reference points (“Stock Status”).

3) The third block of rows reports fishery performance (probability of decreased future yield) relative to the interim management procedure. Specifically, the probabilities correspond to the likelihood of having to reduce yield in future years to return to the reference SPR level (in this case 46%).

4) The fourth section (a single row) illustrates the uncertainty in current fishing intensity via the probability that a given level of harvest might exceed the reference level ($F_{46\%}$) in 2019.

TABLE 3. Harvest decision table for 2019. 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 fishing mortality					Status quo		*Reference SPR=46%*								
		Total mortality (M lb)	0.0	11.7	21.8	31.8	37.6	39.0	40.4	41.8	43.1	44.3	45.5	46.8	48.3	49.9	61.8	
		TCEY (M lb)	0.0	10.0	20.0	30.0	35.8	37.2	38.6	40.0	41.3	42.5	43.7	45.0	46.5	48.1	60.0	
		2019 Fishing intensity	$F_{100\%}$	$F_{78\%}$	$F_{64\%}$	$F_{54\%}$	$F_{49\%}$	$F_{48\%}$	$F_{47\%}$	$F_{46\%}$	$F_{45\%}$	$F_{44\%}$	$F_{43\%}$	$F_{42\%}$	$F_{41\%}$	$F_{40\%}$	$F_{34\%}$	
		Fishing intensity interval	--	56-87%	41-76%	31-67%	27-63%	26-62%	25-61%	25-60%	24-59%	23-59%	23-58%	22-57%	22-56%	21-55%	17-49%	
Stock Trend (spawning biomass)	in 2020	is less than 2019	1	3	26	60	77	81	84	87	90	92	93	95	96	97	>99	a
		is 5% less than 2019	<1	<1	1	10	26	30	34	37	39	41	43	45	48	50	78	b
	in 2021	is less than 2019	1	7	41	75	90	93	94	96	97	98	98	99	99	99	>99	c
		is 5% less than 2019	<1	1	11	42	57	61	65	69	73	77	80	83	87	90	99	d
	in 2022	is less than 2019	1	12	51	82	93	94	96	97	98	98	99	99	99	>99	>99	e
		is 5% less than 2019	<1	3	28	58	76	79	83	86	88	90	92	93	95	96	>99	f
Stock Status (Spawning biomass)	in 2020	is less than 30%	5	7	11	14	17	17	18	18	19	19	20	20	21	21	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	13	20	24	25	25	26	27	27	27	28	29	29	33	i
		is less than 20%	<1	<1	<1	<1	1	1	1	1	2	2	2	3	3	4	10	j
	in 2022	is less than 30%	2	8	17	25	28	29	29	30	30	31	31	32	33	33	41	k
		is less than 20%	<1	<1	<1	2	4	5	6	7	8	9	10	12	13	15	24	l
Fishery Trend (TCEY)	in 2020	is less than 2019	0	<1	18	26	40	45	51	56	60	63	66	69	73	77	95	m
		is 10% less than 2019	0	<1	12	25	29	33	37	42	47	51	54	58	62	66	95	n
	in 2021	is less than 2019	0	<1	20	28	46	51	56	60	64	67	70	73	77	81	97	o
		is 10% less than 2019	0	<1	16	26	35	39	44	49	53	56	59	63	66	71	97	p
	in 2022	is less than 2019	0	<1	22	32	50	54	58	62	66	69	72	76	79	83	98	q
		is 10% less than 2019	0	<1	19	28	40	45	49	53	56	60	62	66	69	73	98	r
Fishery Status (Fishing intensity)	in 2019	is above $F_{46\%}$	0	<1	16	25	35	40	46	50	56	59	62	65	69	72	92	s

The harvest alternatives (columns) provided in the harvest decision table include several extreme levels of mortality (set aside in the left and right sections of the table) intended to provide for evaluation of stock dynamics:

- No fishing 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[4])
- A 60 million pound (~27,200 t) 2019 TCEY

A generally finer grid of alternative TCEY values is provided around the column corresponding to the reference level of fishing intensity (SPR=46%; for 2019 a TCEY of 40 million pounds, ~18,140 t):

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

- The ‘replacement yield’ for the next three year period (a 20 million pound, 9070 t, TCEY) corresponding to a 51/100 chance of stock decrease. This column represents the maximum yield available that will provide a nearly equal chance that the spawning stock is above or below its current level at the end of the projection.
- A 30 million pound (~13,600 t) 2019 TCEY
- A grid of TCEY values corresponding to SPRs from 49-40% in 1% increments.
    - This section includes the TCEY equal to the 2018 mortality limits adopted by each nation (the *status quo*), and the mortality consistent with the reference level of fishing intensity ($F_{46\%}$).

For each column of the decision table, the total projected mortality of all sizes and from all sources, the coastwide TCEY and the associated level of fishing intensity (median value with the 95% credible range 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.

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% (Table 3, Figure 18). 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% (Figure 19). The reference level corresponds to an 87/100 (87%) chance of stock decline through 2020. There is less than a one third chance (<34/100) that the stock will decline below the threshold reference point ($SB_{30\%}$) in any year for projections evaluated over three years with all the levels of fishing intensity up to and including an SPR of 40%.

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-2019-AM095-14**). The development of the 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.

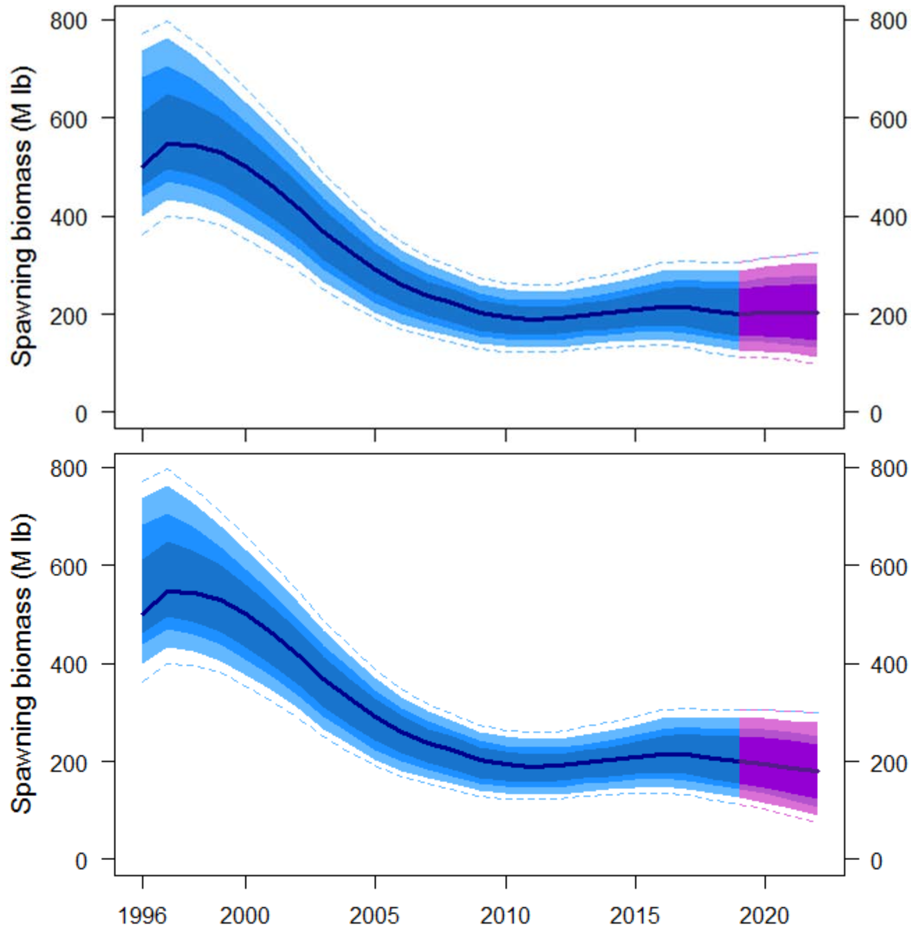

FIGURE 18. Three-year projections of stock trend under an SPR=64% (TCEY=20.0 million pounds, ~9070 t; upper panel) and an SPR=48% (TCEY=37.2 million pounds, ~16,880 t; equivalent to the 2018 *status quo*; lower panel).

Technical development: 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 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. In preparation for the upcoming independent scientific peer review of the stock assessment models and methods for creating the ensemble, technical research priorities include:

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

2) Incorporation of sex-ratio at age information from genetic analysis of 2017 commercial landings.

3) Incorporation of a refined modelled FISS time-series applying whale depredation criteria refined for 2018 (**IPHC-2019-AM095-06**) to the entire survey data set (1993-2017), and re-analyzing these data with the space-time model (**IPHC-2019-AM095-07**) for use in the stock assessment models.

4) Updating the software on which the individual assessment models are developed to the most recently available version of stock synthesis in order to allow evaluation of newly available features of potential utility to the Pacific halibut assessment. These include estimation of observation error variance terms, process error variance terms, and other features to be explored.

5) Continued refinement of the ensemble of models used in the stock assessment, potentially including new models with a more broad range of natural mortality estimates, particularly for the short time-series models.

6) Continued development of weighting approaches for models included in the ensemble, potentially including fit to the survey index of abundance, retrospective, and predictive performance.

7) Exploration of methods for better including uncertainty in discard mortality and bycatch estimates in the assessment (now evaluated only via alternative mortality projection tables or model sensitivity tests) in order to better include these sources uncertainty in the decision table.

8) 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.

ACKNOWLEDGEMENTS

We thank all of the IPHC Secretariat staff for their contributions to data collection, analysis and preparation for the stock assessment. We also thank the staff at the NMFS, DFO, ADFG, WDFW, ODFW, and CDFW for providing the annual information required for this assessment in a timely manner. The SRB and the Science Advisors provided critical review and helpful guidance during the 2018 process.

RECOMMENDATION/S

That the Commission:

a) **NOTE** paper IPHC-2019-AM095-09 which provides the results of the 2018 stock assessment for Pacific halibut.

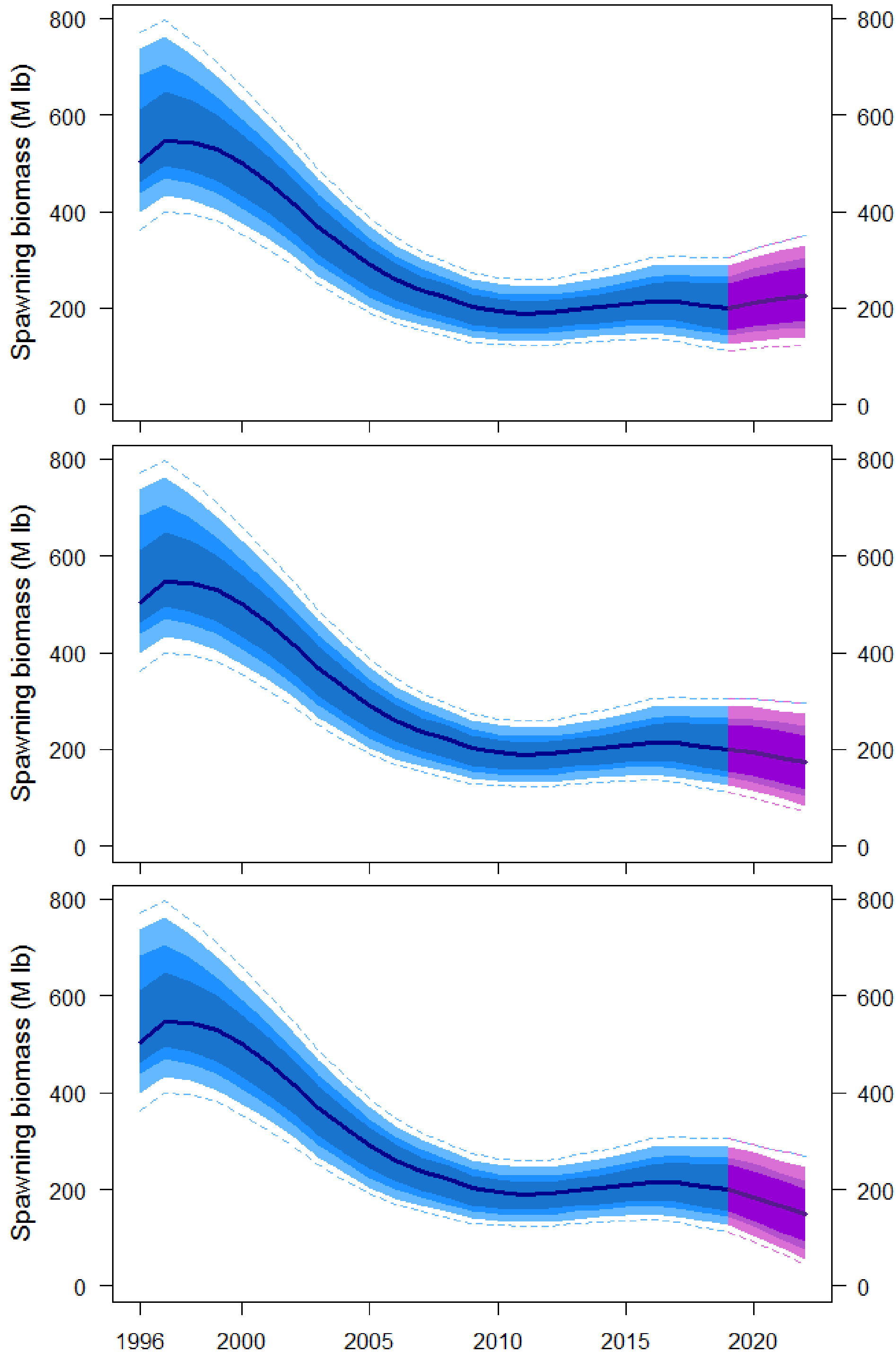

FIGURE 19. Three-year projections of stock trend under alternative levels of mortality: no fishing mortality (upper panel), Reference SPR=46% (40.0 million pounds, ~18,100 t; middle panel) and a TCEY of 60 million pounds (~27,200 t; lower panel).

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