Stock Assessment: Summary of the data, stock assessment, and harvest decision table for Pacific halibut (*Hippoglossus stenolepis*) at the end of 2020

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PURPOSE

To provide the Commission with a summary of the data, stock assessment, and harvest decision table at the end of 2020.

INTRODUCTION

In 2020 the International Pacific Halibut Commission (IPHC) undertook its annual coastwide stock assessment of Pacific halibut (*Hippoglossus stenolepis*). This assessment represents an update to the 2019 stock assessment (Stewart and Hicks 2020), with incremental changes documented through a two-part review by the IPHC's Scientific Review Board (SRB; IPHC-2020-SRB016-R, IPHC-2020-SRB017-R). Changes, new data, and extensions to existing time-series for 2020 include:

1) Update the version of stock synthesis used for the analysis (3.30.15.09).
2) Add sex-specific recreational age composition data from IPHC Regulatory Area 3A (and allow for sex-specific differences in selectivity) where previously only sexes-aggregated age compositions were available.
3) Include newly available sex-ratios-at-age for the 2019 commercial fishery (building on the 2017 and 2018 sex-ratios used in the 2019 stock assessment).
4) New modelled trend information from the 2020 fishery-independent setline survey (FISS) including predictions covering both sampled and unsampled (but informed by covariates and the temporal correlation parameters) IPHC Regulatory Areas.
5) Age, length, individual weight, and average weight-at-age estimates from the 2020 FISS for all sampled IPHC Regulatory Areas.
6) 2020 (and a small amount of 2019) commercial fishery logbook trend information from all IPHC Regulatory Areas.
7) 2020 commercial fishery biological sampling (age, length, individual weight, and average weight-at-age) from all IPHC Regulatory Areas.
8) Biological information (lengths and/or ages) from non-directed discards (all IPHC Regulatory Areas) and the recreational fishery (IPHC Regulatory Area 3A only) from 2019.
9) Updated mortality estimates from all sources for 2019 (where preliminary values were used) and estimates for all sources in 2020.

Overall, model results remain highly consistent with those of recent stock assessments. Spawning biomass trends continue downward, although the 2020 assessment reports less decline than anticipated, partly as a function of mortality reductions in 2020. The 2011 and 2012 year-classes, estimated to be stronger than any since 2005 remain uncertain and are highly important to short-term projections of stock and fishery dynamics.

This document provides an overview of the final data sources available for the 2020 Pacific halibut stock assessment including the population trends and distribution among Regulatory

Areas based on the modelled IPHC FISS, directed commercial fishery data, and results of the stock assessment including all data available through 2020.

STOCK AND MANAGEMENT

The stock assessment reports the status of the Pacific halibut 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 the Salish Sea, but excludes known extremities in the western Bering Sea within the Russian Exclusive Economic Zone (Figure 1).

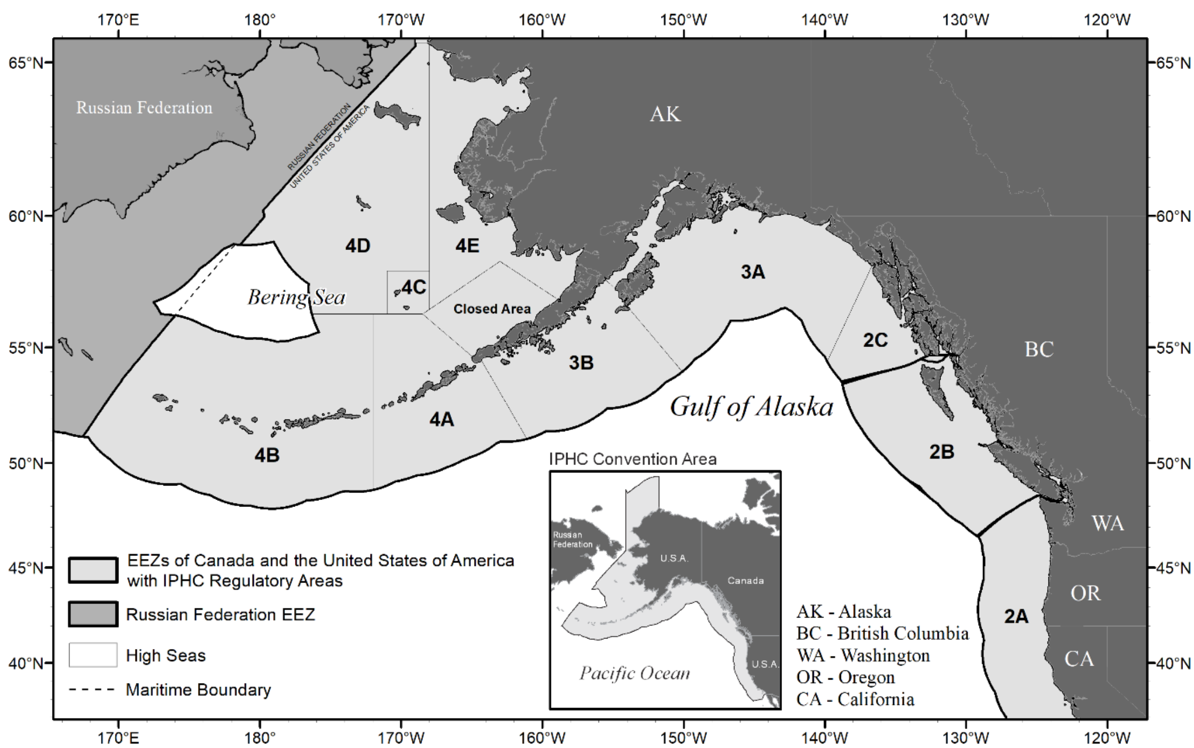

FIGURE 1. IPHC Convention Area (insert) and IPHC Regulatory Areas.

The Pacific halibut fishery has been managed by the IPHC since 1923. Mortality limits for each of eight IPHC 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 short-term 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.

DATA

Historical mortality

Known Pacific halibut mortality consists of target commercial fishery landings and discard mortality (including research), recreational fisheries, subsistence, and discard mortality in fisheries targeting other species ('non-directed' fisheries where Pacific halibut retention is

[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.

prohibited). Over the period 1921-2020 mortality has totaled 7.3 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 mortality was above this long-term average from 1985 through 2010, and has averaged 40 million pounds (~18,000 t) from 2016-20.

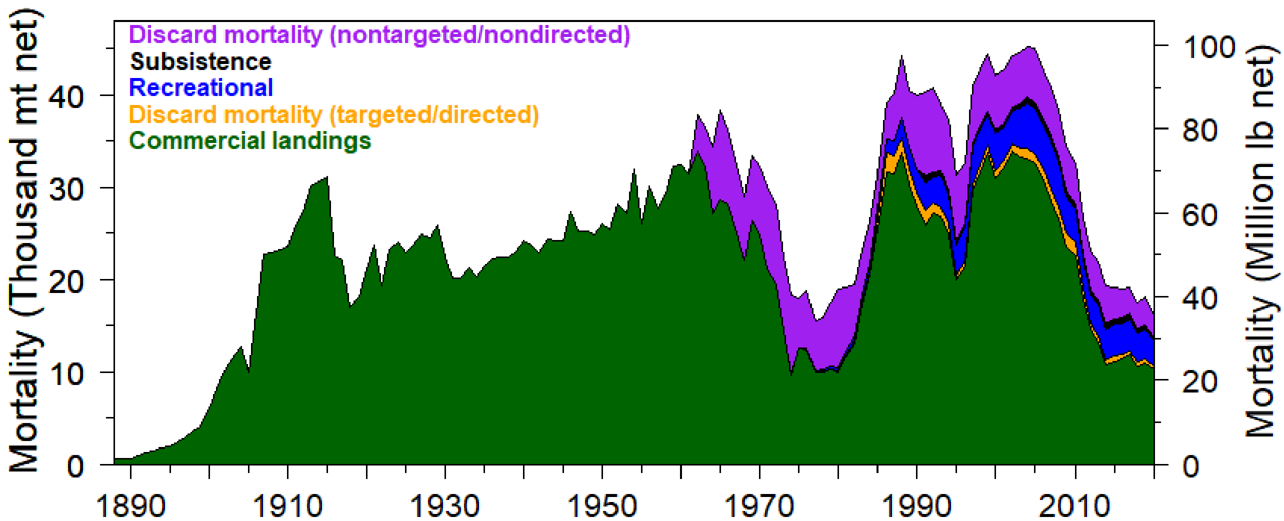

FIGURE 2. Summary of estimated historical mortality by source (colours), 1888-2020.

2020 Fishery and IPHC fishery-independent setline survey (FISS) statistics

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 2020, the most important information came from the modelled index of abundance reflecting the 2020 FISS, and the associated biological sampling. Sex-ratios at age were available for the first time from: 1) commercial fishery landings in 2019 (building on the data for 2017 and 2018 previously available), and 2) the full time-series (1994-2019) of age data from recreational fisheries in the Gulf of Alaska (IPHC Regulatory Area 3A) provided by Alaska Department of Fish and Game. Routine updates of logbook records from the 2019 (and earlier) directed commercial fishery, as well as age-frequency observations and individual weights from the commercial fishery were also included. Beginning in 2019, individual weights have been collected during FISS operations such that WPUE and stock distribution estimates are calculated directly, without the use of the historical weight-length relationship. All mortality estimates (including changes to the existing time-series where new estimates have become available) were extended to include 2020. All available information was finalized on 31 October 2020 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 the year (i.e. mortality estimates for ongoing fisheries or for fisheries where final estimation is still pending).

Data for stock assessment use are 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 mortality estimates from all sources, modelled indices of abundance (IPHC-2020-IM096-06 based on the IPHC's annual fishery-independent setline survey (FISS; in numbers and weight) and other surveys), commercial Catch-Per-Unit-Effort (in weight), and biological summaries from both sources (length-, weight-, and age-composition data).

Coastwide commercial Pacific halibut fishery landings (including research landings) in 2020 were approximately 22.7 million pounds (~11,400 t), down 6% from 2019[2]. Discard mortality in non-directed fisheries was estimated to be 5.0 million pounds in 2020 (~2,280 t)[3], down 23% from 2019 and representing the smallest estimate in the time-series. The total recreational mortality (including estimates of discard mortality) was estimated to be 6.0 million pounds (~2,700 t) down 15% from 2019 due to several sectors not reaching the full regulatory limit or projected level. Mortality from all sources decreased by 11% to an estimated 35.5 million pounds (~16,100 t) in 2020 based on preliminary information available through 31 October 2020.

The 2020 modelled FISS results detailed a coastwide aggregate NPUE which decreased by 1% from 2019 to 2020, the fourth consecutive year of a decreasing trend (Figure 3). Biological Region 2 declined by 8% to the lowest estimate in the time-series, while Biological Region 3 increased by 1%. Although not directly sampled in 2020, Biological Regions 4, and 4B were projected to go up slightly; uncertainty intervals were correspondingly large. The 2019 modelled coastwide WPUE of legal (O32) Pacific halibut, the most comparable metric to observed commercial fishery catch rates, increased by 6% from 2019 to 2020. This positive trend relative to that for NPUE indicates that somatic growth, primarily of O32 Pacific halibut is contributing more to current stock productivity than incoming recruitment. Individual IPHC Regulatory Areas varied from a 24% increase (Regulatory Area 3A) to a 10% decrease (Regulatory Area 2B; Figure 4) in O32 WPUE. Uncertainty was greater in IPHC Regulatory Areas that were not directly sampled in 2020 (2A, 4A, 4B, and 4CDE), but still comparable with the recent time-series due to the spatial and temporal correlations in the data that are captured in the space-time modelling.

[2] The mortality estimates reported in this document are those available at the end of October 2020, and used in the assessment analysis; they include projections through the end of the fishing season.

[3] The IPHC receives preliminary estimates of the current year's non-directed commercial discard 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. Where necessary, projections are added to approximate the total mortality through the end of the calendar year. Further updates are anticipated in January 2021 and will be incorporated into final projections for 2021.

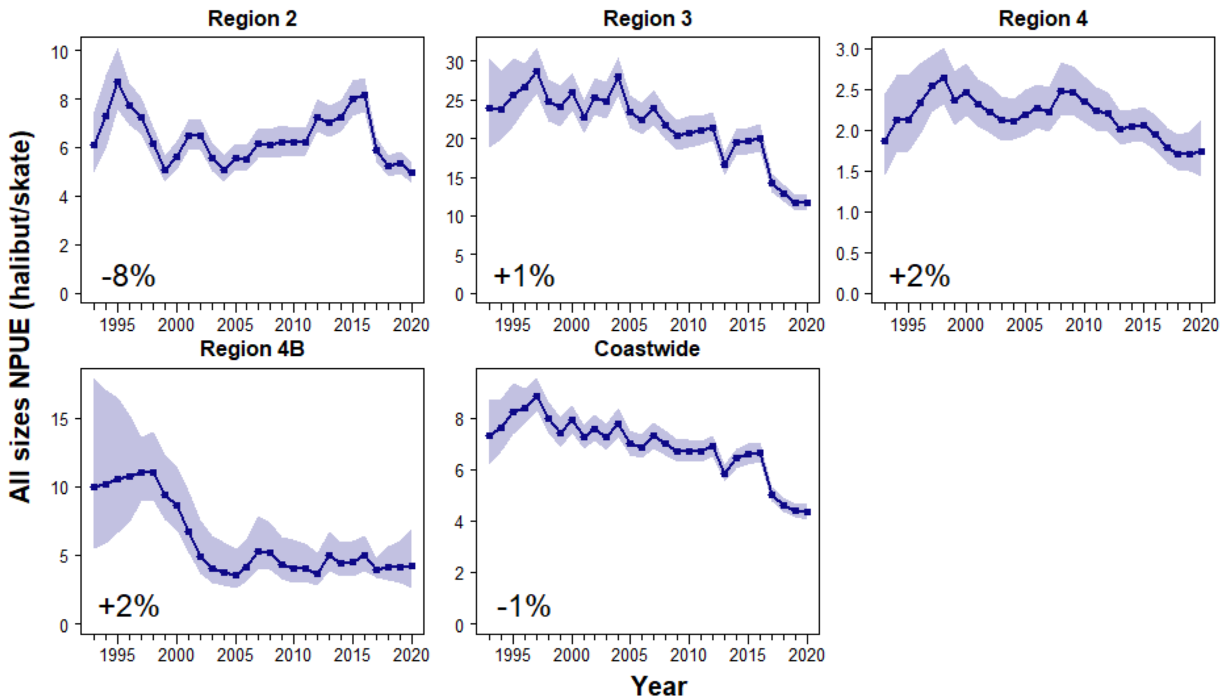

FIGURE 3. Trends in modelled FISS NPUE by Biological Region, 1993-2020. Percentages indicate the change from 2019 to 2020. Shaded zones indicate approximate 95% credible intervals.

Preliminary commercial fishery WPUE estimates from 2020 logbooks increased by 2% at the coastwide level (Figure 5). The bias correction to account for additional logbooks compiled after the fishing season resulted in an estimate of no change coastwide. Trends varied among IPHC Regulatory Areas and gears, with generally positive trends observed in IPHC Regulatory Areas 2A, 2C, 3B, 4C and 4D. The largest decreases were observed in IPHC Regulatory Areas 2B and 4B, and these are likely to be even larger when 2020 logbook records are complete.

Biological information (ages and lengths) from the commercial fishery continue to show the 2005 year-class as the largest coastwide contributor (in number) to the fish encountered. In the 2020 fishery, for the first time the 2011 and 2012 year-classes were clearly present, indicating that their individual growth rates have moved them partially above the current 32 inch (81.3 cm) minimum size limit. The age data collected by the FISS observed the 2011 and 2012 cohorts (now 8 and 9 years old), for the third consecutive year. These cohorts represented the largest proportions in the total catch for some IPHC Regulatory Areas. Recognizing that no sampling occurred in IPHC Regulatory Areas 2A, 4A, 4B and 4CDE in 2020, historical cohorts have generally been widely and relatively uniformly distributed by ages 8-10. Individual size-at-age appears to be increasing for younger ages (<14) in some IPHC Regulatory Areas (particularly notable in 3A). Size-at-age trends tend to take years to change appreciably, so it may be some time before strong conclusions can be drawn regarding whether recent observations represent a change in long-term trends or annual variability. Direct estimates of the sex-ratio at age for the directed commercial fishery were first available for 2017 and 2018 in the 2019 stock assessment. For 2020, the 2019 observations (identified via genetic assays of samples from the commercial landings) again indicated a high percentage of female Pacific halibut in the landings (78% coastwide) and a slight downward trend over the three years with data (from 82% in 2017).

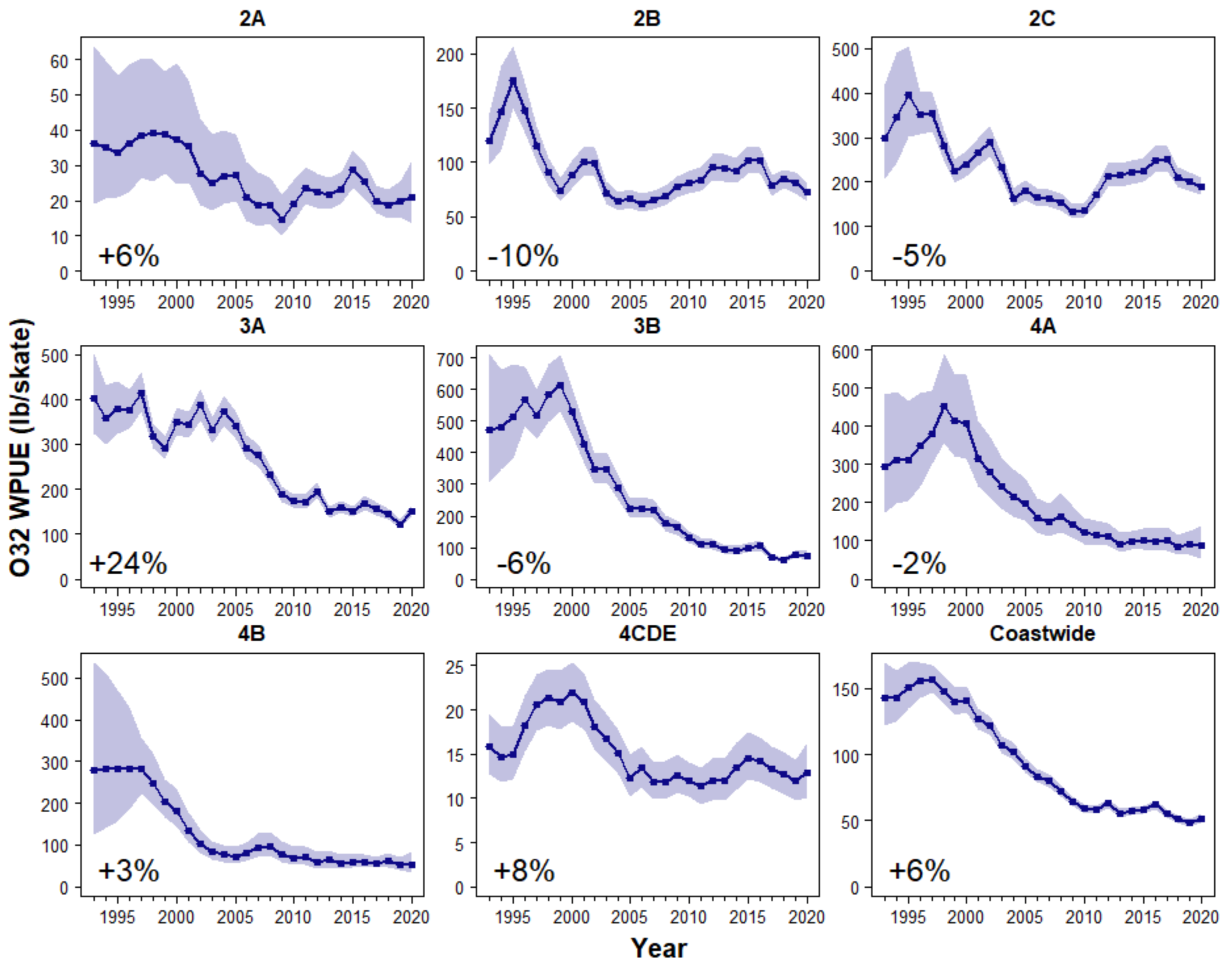

FIGURE 4. Trends in modelled FISS legal (O32) WPUE by IPHC Regulatory Area, 1993-2020. Percentages indicate the change from 2019 to 2020. Shaded zones indicate approximate 95% credible intervals. Note that IPHC Regulatory Areas 2A, 4A, 4B and 4CDE represent projections based on the space-time model in the absence of 2020 sampling.

Biological stock distribution

Updated trends indicate that population distribution (measured via the modelled FISS catch in weight of all Pacific halibut) has largely been decreasing in Biological Region 3 since 2004, and increasing in Biological Regions 2 and 4 (Figure 6; recent years in Table 1). However, in 2020 there was a notable increase in Biological Region 3 and a decrease in Biological Region 2. Biological Region 4 remained near the historical high, with the caveat that the 2020 value represents a space-time model prediction in the absence of direct sampling. Survey data are insufficient to estimate stock distribution prior to 1993. It is therefore unknown how historical distributions or the average distribution in the absence of fishing mortality may compare with recent observations.

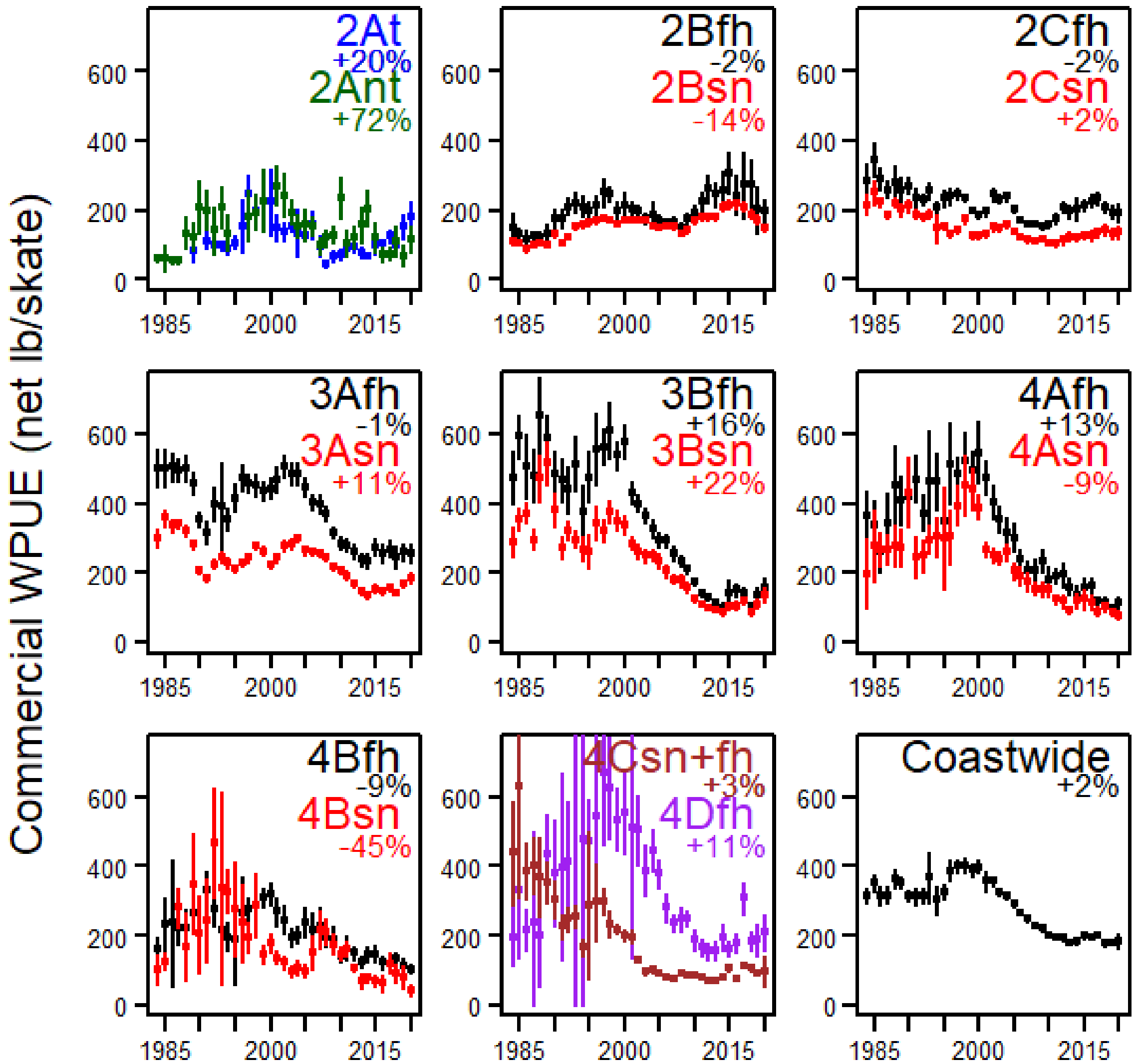

FIGURE 5. Trends in commercial fishery WPUE by IPHC Regulatory Area and fishery or gear, 1984-2020. The tribal fishery in 2A is denoted by “2At”, non-tribal by “2Ant”, fixed hook catch rates by “fh” and snap gear catch rates by “sn” for IPHC Regulatory Areas 2B-4D. Percentages indicate the change from 2019 to 2020 uncorrected for bias due to incomplete logbooks (see text above). Vertical lines indicate approximate 95% confidence intervals.

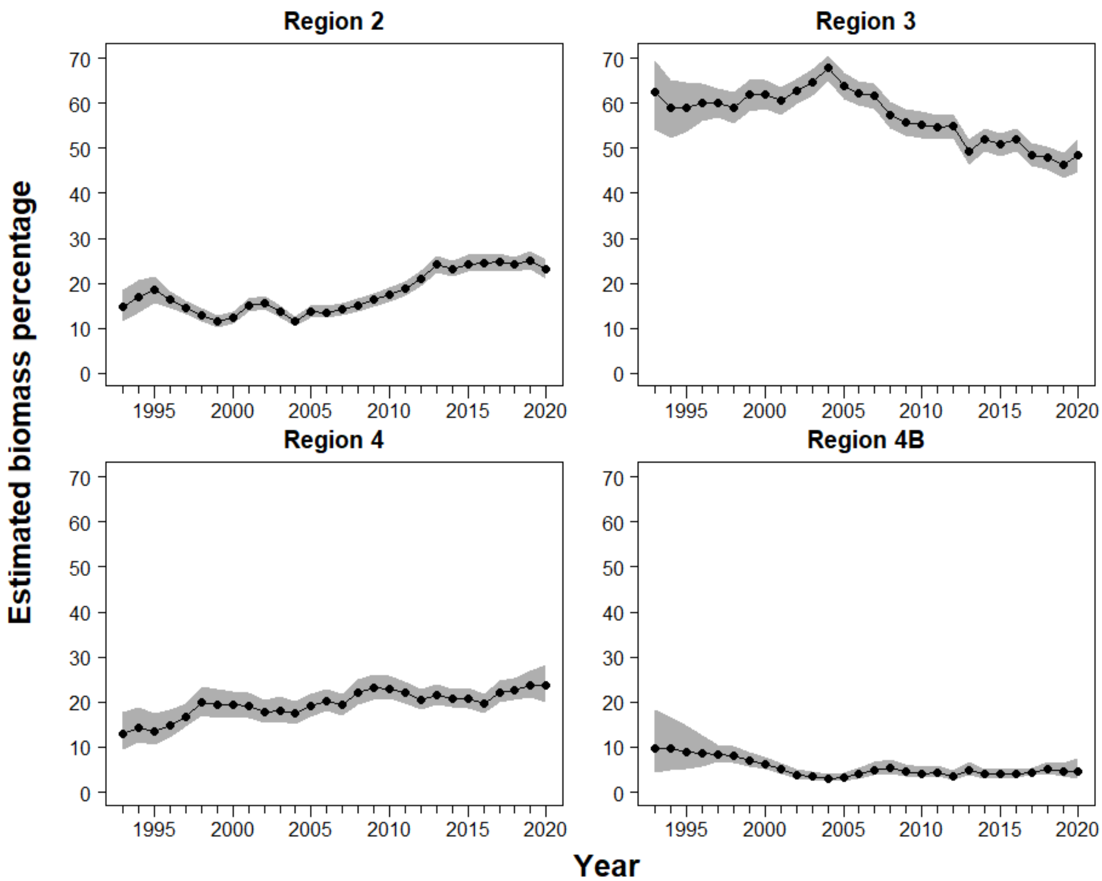

FIGURE 6. Estimated stock distribution (1993-2020) based on modelled survey catch of all sizes of Pacific halibut. Shaded zones indicate approximate 95% credible intervals.

TABLE 1. Recent stock distribution estimates by Biological Region based on modelling of all Pacific halibut captured by the FISS.

Year	Region 2 (2A, 2B, 2C)	Region 3 (3A, 3B)	Region 4 (4A, 4CDE)	Region 4B
2016	24.4%	51.9%	19.6%	4.1%
2017	24.7%	48.6%	22.3%	4.5%
2018	24.2%	47.9%	22.8%	5.2%
2019	25.0%	46.4%	23.9%	4.7%
2020	23.1%	48.5%	23.6%	4.7%

STOCK ASSESSMENT

This stock assessment continues to be implemented using the generalized software stock synthesis (Methot 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 1992 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 Biological 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), and other model parameters.

The 2019 stock assessment was a full analysis, including a complete re-evaluation of all data sources and modelling choices, particularly those needed to accommodate the newly available sex-ratio at age data from the commercial fishery. The 2020 stock assessment represents an update to the 2019 analysis, adding data sources where available, but retaining the same basic model structure for each of the four component models. Incremental changes made during 2020 were documented through a two-part review by the IPHC's scientific review process (IPHC-2020-SRB016-R, IPHC-2020-SRB017-R).

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 uncertainty provides a basis for risk assessment and reduces the potential for abrupt changes in management quantities as improvements and additional data are added to individual models. The four models continue to be equally weighted. Within-model uncertainty was propagated through to the ensemble results via the maximum likelihood estimates and an asymptotic approximation to individual model variance estimates. 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 2020 stock assessment indicate that the Pacific halibut stock declined continuously from the late 1990s to around 2012 (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. The spawning biomass (SB) is estimated to have increased gradually to 2016, and then decreased to an estimated 192 million pounds (~87,050 t) at the beginning of 2021, with an approximate 95% credible interval ranging from 125 to 292 million pounds (~56,800-132,600 t; Figure 8). The recent spawning biomass estimates from the 2020 stock assessment are very consistent with previous analyses, back to 2012 (Figure 9). Prior to that period, the current assessment indicates a high probability of larger biomass than estimated prior to the 2019 stock assessment; this is largely the result of the addition of sex-ratio information for the directed commercial landings. All assessments since 2015 have indicated a decreasing spawning biomass in the terminal year.

Average Pacific halibut recruitment is estimated to be higher (70 and 75% 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 2019 were positive, with 2020 showing negative average conditions through September. Although strongly correlated with historical recruitments, it is unclear whether recent anomalous conditions in both the Bering Sea and Gulf of Alaska (especially since 2014) are comparable to those observed in previous decades.

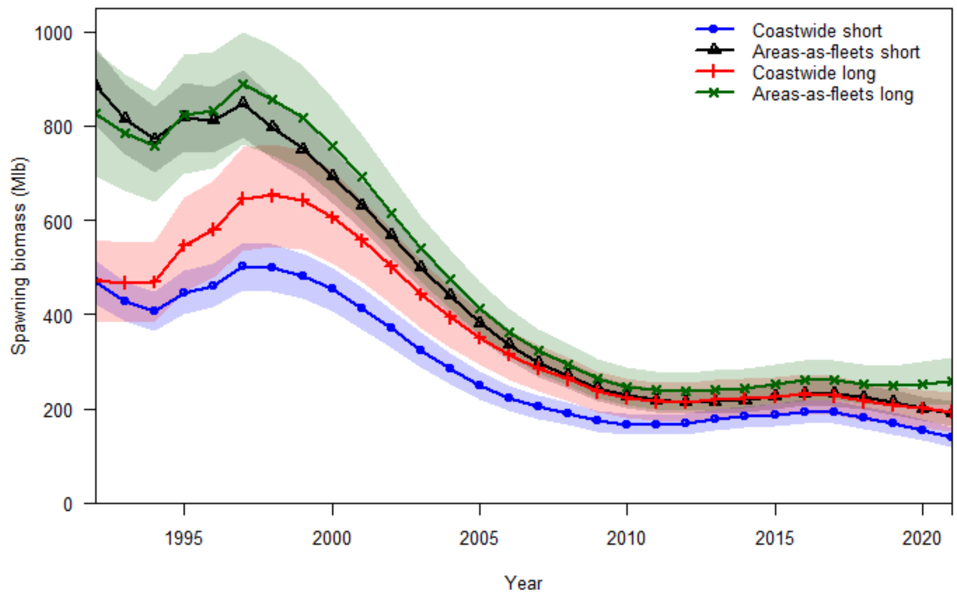

FIGURE 7. Estimated spawning biomass trends (1992-2021) based on the four individual models included in the 2020 stock assessment ensemble. Series indicate the maximum likelihood estimates; shaded intervals indicate approximate 95% credible intervals.

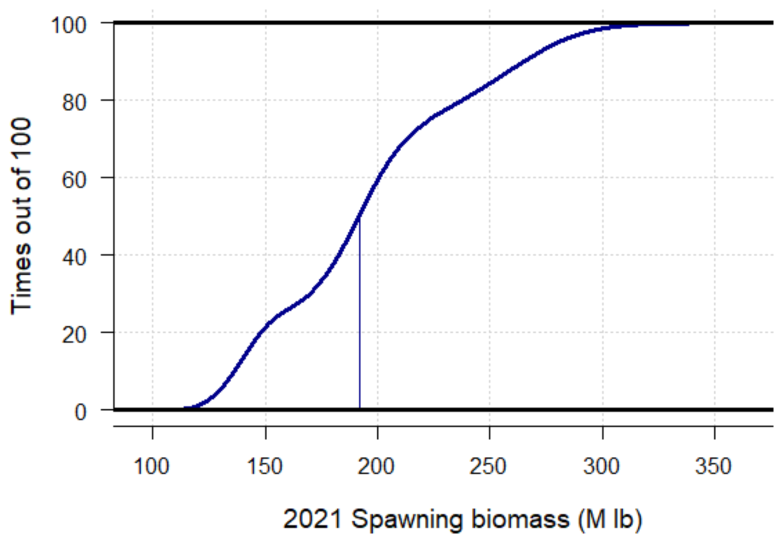

FIGURE 8. Cumulative distribution of the estimated spawning biomass at the beginning of 2020. Curve represents the estimated probability that the biomass is less than or equal to the value on the x-axis; vertical line represents the median (192 million pounds, ~87,050 t).

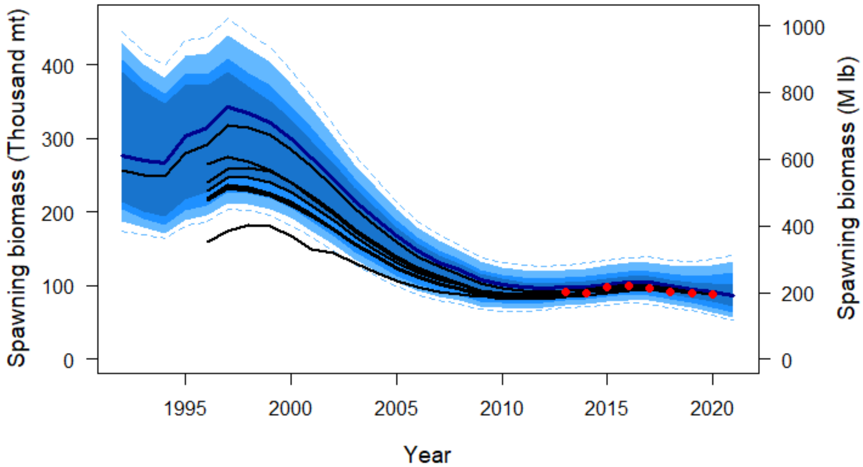

FIGURE 9. Retrospective comparison among recent IPHC stock assessments. Black lines indicate estimates of spawning biomass from assessments conducted in 2012-2019 with the terminal estimate shown as a red point. The shaded distribution denotes the 2020 ensemble: the dark blue line indicates the median (or “50:50 line”) with an equal probability of the estimate falling above or below that level; and 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.

Pacific halibut recruitment estimates show the large cohorts in 1999 and 2005 (Figure 10). Cohorts from 2006 through 2010 are estimated to be much smaller than those from 1999-2005, which results in a high probability of near-term decline in both the stock and fishery yield as these low recruitments become increasingly important to the age range over which much of the harvest and spawning takes place. Based on age data through 2020, individual models in this assessment produced estimates of the 2011 and 2012 year-classes that ranged extensively: from below to above the magnitude of the 2005 year-class. Even with a third year of observation from the FISS, and now a year from the commercial fishery, these two important year-classes remain uncertain. Some of this uncertainty is due to the relatively flat trends observed which do not clearly identify these cohorts as being above average, despite the strong representation in the age structure of the samples. The projected spawning biomass over the next 3 years includes the effects of these year classes maturing at ages 8-12.

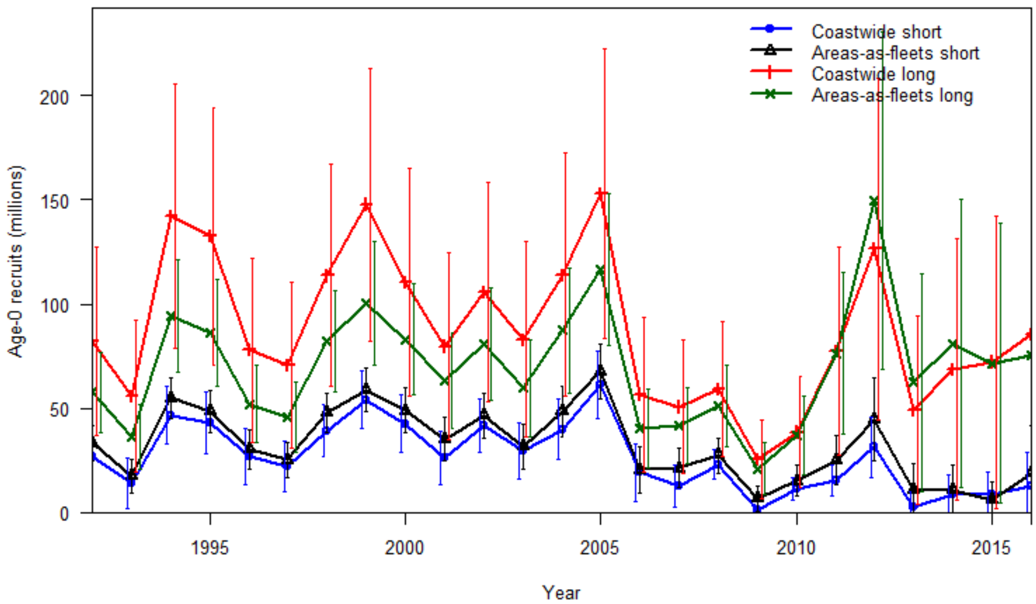

FIGURE 10. Estimated age-0 recruitment trends (1992-2016) based on the four individual models included in the 2020 stock assessment ensemble. Series indicate the maximum likelihood estimates; vertical lines indicate approximate 95% credible intervals.

The IPHC's interim management procedure uses a relative spawning biomass of 30% as a trigger, below which the target fishing intensity is reduced. At a spawning biomass limit of 20%, directed fishing is halted due to the critically low biomass condition. Beginning with the 2019 stock assessment, this calculation has been based on recent biological conditions rather than a long-term static average. By using current weight-at-age and estimated recruitments influencing the current stock only, the 'dynamic' calculation measures the effect of fishing on the spawning biomass. The relative spawning biomass in 2021 was estimated to be 33% (credible interval: 22-52%) down slightly from 34% in 2020, but greater than the values estimated for the previous decade. The probability that the stock is below the $SB_{30\%}$ level is estimated to be 41% at the beginning of 2021, with less than a 1% chance that the stock is below $SB_{20\%}$. The two long time-series models (coastwide and areas-as-fleets) show different results when comparing the current stock size to that estimated at the historical low in the 1970s. The AAF model estimates that recent stock sizes are well below those levels, and the coastwide model above. The relative 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.

The IPHC's current interim management procedure specifies a target level of fishing intensity of a Spawning Potential Ratio (SPR) corresponding to an $F_{43\%}$; this equates to the level of fishing that would reduce the lifetime spawning output per recruit to 43% of the unfished level given current biology, fishery characteristics and demographics. Based on the 2020 assessment, the 2020 fishing intensity is estimated to correspond to an $F_{48\%}$ (credible interval: 34-65%; Table 2), less than values estimated over the previous decade. This drop in fishing intensity corresponds to the reduction in mortality limits adopted for 2020 and the actual mortality of several sectors totaling less than predicted. Comparing the relative spawning biomass and fishing intensity over the recent historical period provides for an evaluation of trends conditioned on the currently defined reference points via a 'phase' plot. The phase plot for Pacific halibut shows that the relative spawning biomass decreased as fishing intensity increased through 2010, then increased as the fishing intensity decreased through 2016, and has been relatively stable since then (Figure 11).

TABLE 2. Status summary of Pacific halibut in the IPHC Convention Area at beginning of 2021.

Indicators	Values	Trends	Status
Total mortality 2020: Retained catch 2020: Average removals 2016–20:	35.50 MLBS, 16,103 T[1] 29.65 MLBS, 13,449 T 39.59 MLBS, 17,959 T	MORTALITY DECREASED FROM 2019 TO 2020	**2020 MORTALITY NEAR 100-YEAR LOW**
SPR_{2020}: P(SPR<43%): P(SPR<limit):	48% (34-65%)[2] 38% LIMIT NOT SPECIFIED	FISHING INTENSITY DECREASED FROM 2019 TO 2020	**FISHING INTENSITY BELOW REFERENCE LEVEL[3]**
SB_{2021} (MLBS): SB_{2021}/SB_0: $P(SB_{2021}<SB_{30})$: $P(SB_{2021}<SB_{20})$:	192 MLBS (125–292) 33% (22-52%) 41% <1%	SB DECREASED 17% FROM 2016 TO 2021	**NOT OVERFISHED[4]**
Biological stock distribution:	SEE TABLES AND FIGURES	REGION 4 INCREASING	**REGION 4 NEAR HISTORICAL HIGH**

[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 43%.
[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. Although this is an improvement over the use of a single assessment model, there are important sources of uncertainty that are not included.

The assessment utilized three years (2017-19) of sex-ratio information from the directed commercial fishery landings. However, uncertainty in historical ratios, and the degree of variability likely present in those and future fisheries remains unknown. Additional years of data are likely to further inform selectivity parameters and cumulatively reduce uncertainty in stock size in the future; efforts to better understand historical sex-ratios are underway. The treatment of spatial dynamics and movement rates among Biological Regions, 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. This assessment also does not include mortality, trends or explicit demographic linkages with Russian waters, although such linkages may be increasingly important as warming waters in the Bering Sea allow for potentially important exchange across the international border.

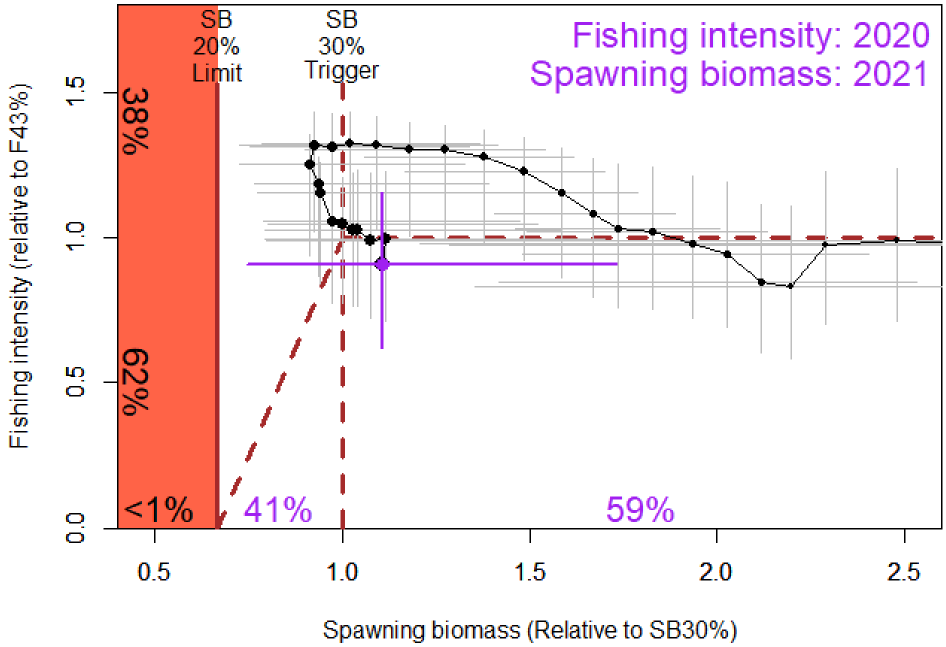

FIGURE 11. Phase plot showing the time-series (1992-2021) of estimated spawning biomass and fishing intensity relative to the reference points specified in the IPHC's interim management procedure. Dashed lines indicate the current $F_{43\%}$ (horizontal) reference fishing intensity, with linear reduction below the $SB_{30\%}$ (vertical) trigger, the red area indicates relative spawning biomass levels below the $SB_{20\%}$ limit. Each year of the time series is denoted by a solid point (credible intervals by horizontal and vertical whiskers), with the relative fishing intensity in 2020 and spawning biomass at the beginning of 2021 shown as the largest point (purple). Percentages along the y-axis indicate the probability of being above and below $F_{43\%}$ in 2020; percentages on the x-axis the probabilities of being below $SB_{20\%}$, between $SB_{20\%}$ and $SB_{30\%}$ and above $SB_{30\%}$ at the beginning of 2021.

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 have been a critically important driver of stock trends, but its cause also remains unknown. Like most stock assessments, mortality estimates are assumed to be accurate. Therefore, uncertainty due to discard 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.

Maturation schedules are currently under renewed investigation by the IPHC. Currently used historical values are based on visual field assessments, and the simple assumption that fecundity is proportional to spawning biomass and that Pacific halibut do not experience appreciable skip-spawning (physiologically mature fish which do not actually spawn due to environmental or other conditions). To the degree that maturity, fecundity or skip spawning may be temporally variable, the current approach could result in bias in the stock assessment trends and reference points. New information will be incorporated as it becomes available; however, it may take years to better understand these biological processes at the scale of the entire population.

Due to the many remaining uncertainties in Pacific halibut biology and population dynamics, a high degree of uncertainty in both stock scale and trend will continue to be an integral part of an annual management process. Results of the IPHC's Management Strategy Evaluation (MSE) process can inform management procedures that are robust to estimation uncertainty via the stock assessment, and to a wide range of hypotheses describing population dynamics.

OUTLOOK

Stock projections were conducted using the integrated results from the stock assessment ensemble in tandem with summaries of the 2020 directed and non-directed fisheries. 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 2021 (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 levels of mortality intended for evaluation of stock and management procedure dynamics including:

- No mortality (useful to evaluate the stock trend due solely to population processes)
- The mortality at which there is a 50% chance that the spawning biomass will be smaller in three years than in 2021 ("*3-year surplus*")
- The mortality consistent with repeating the TCEY set for 2019 (36.6 million pounds, 16,600 t; *"status quo"*).
- The mortality consistent with the current "Reference" SPR ($F_{43\%}$) level.
- A 60 million pound (~27,200 t) 2021 TCEY

A grid of alternative TCEY values corresponding to SPR values from 40% to 46% is also provided to allow for finer detail across the range of estimated SPR values identified by the MSE process as performing well with regard to stock and fishery objectives. For each row of the decision table, the mortality (including all sizes and sources), the coastwide TCEY and the associated level of fishing intensity projected for 2021 (median value with the 95% credible interval below) are reported.

The projections for this assessment are slightly more optimistic than in the 2019 assessment; however, a high probability of stock decline (approximately 2/3) is estimated for the entire range of SPR values from 40-46%. The stock is projected to decrease with at least a 51% chance over the period from 2021-23 for all TCEYs greater than the "3-year surplus" of 24.4 million pounds (~11,068 t), corresponding to a projected SPR of 58% (credible interval 39-76%; Table 3, Figure 12). At the *status quo* TCEY (36.6 million lb, (~16,600 t), the probability of spawning biomass declines is 62 and 61% for one and three years respectively. At the reference level (a projected SPR of 43%) the probability of spawning biomass decline to 2022 is 65%, decreasing to 63% in three years, as the 2011 and 2012 cohorts mature. The one-year risk of the stock dropping below

$SB_{30\%}$ ranges from 35% (at the 3-year surplus level) to 41% at the reference TCEY. Over three years these probabilities range from 29% to 44% depending on the level of mortality.

TABLE 3. Harvest decision table for 2021 mortality limits. Columns correspond to yield alternatives and rows to risk metrics. Values in the table represent the probability, in “times out of 100” (or percent chance) of a particular risk.

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

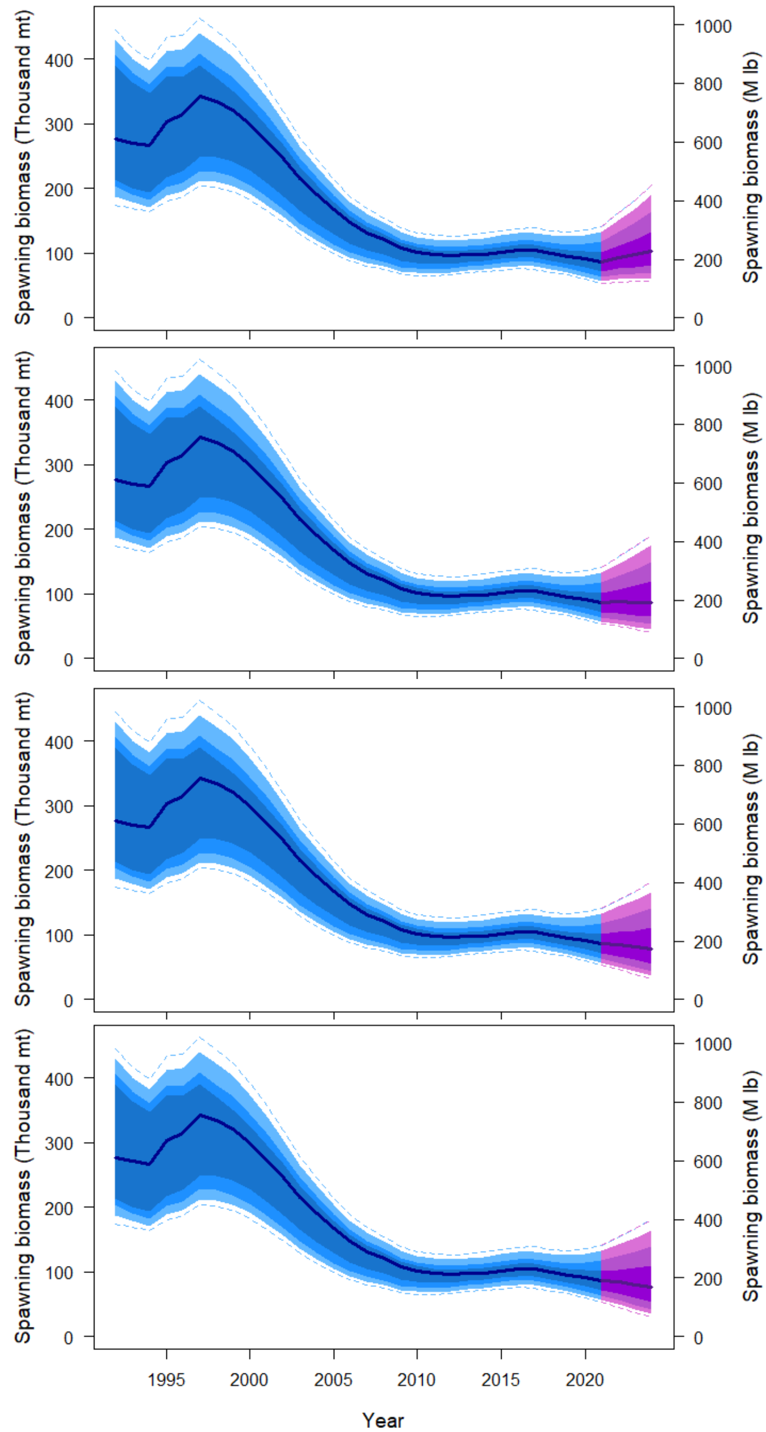

FIGURE 12. Three-year projections of stock trend under alternative levels of mortality: no fishing mortality (upper panel), the 3-year surplus (a TCEY of 24.4 million pounds, ~11,068 t; second panel), the *status quo* TCEY from 2020 of 36.6 million pounds, 16,600 t; third panel), and the TCEY projected for the IPHC's interim management procedure (39.0 million pounds, 17,690 t; lower panel).

SCIENTIFIC ADVICE

Sources of mortality: In 2020, total Pacific mortality due to fishing was down to 35.50 million pounds (16,103 t) from 39.87 million pounds (18,086 t) in 2019 (updated for this assessment). Of that total, 84% comprised the retained catch, up from 81% in 2019 (Table 3).

Fishing intensity: The 2020 mortality corresponded to a point estimate of SPR = 48%; there is a 38% chance that fishing intensity exceeded the IPHC's current reference level of 43% (Table 3). The Commission does not currently have a coastwide fishing intensity limit reference point.

Stock status (spawning biomass): Current (beginning of 2021) female spawning biomass is estimated to be 192 million pounds (87,050 t), which corresponds to an 41% chance of being below the IPHC trigger reference point of $SB_{30\%}$, and less than a 1% chance of being below the IPHC limit reference point of $SB_{20\%}$. The stock is estimated to have declined by 17% since 2016 but is currently at 33% of the unfished state. Therefore, the stock is considered to be '**not overfished**'. Projections indicate that mortality consistent with the interim management procedure reference fishing intensity ($F_{43\%}$) is likely to result in further declining biomass levels in the near future.

Stock distribution: The proportion of the coastwide stock represented by Biological Region 3 has been largely decreasing since 2004 (Figure 6), and increasing in Biological Regions 2 and 4. However, there was an increase in Biological Region 3 in 2020 and a decrease in Biological Region 2. Biological Region 4 is near the historical high estimated for 2019, and has shown an increasing trend since the early 1990s.

RESEARCH PRIORITIES

Research priorities for the stock assessment and related analyses have been consolidated with those for the IPHC's MSE and the Biological Research program and are included in the IPHC's five-year research plan.

DETAILED MANAGEMENT INFORMATION

The IPHC's current interim management procedure, in place for 2021-22, includes setting a coastwide TCEY, and also a method for distributing that TCEY among IPHC Regulatory Areas. The distribution method includes the current estimate of stock distribution, relative harvest rates by IPHC Regulatory Area, specific adjustments to the TCEY in IPHC Regulatory Areas 2A and 2B, as well as an increase in the TCEY in IPHC Regulatory Area 2B accounting for the U26 non-directed discard mortality in Alaska. Details of the calculation framework are provided in IPHC-2021-AM097-INF02. The 2021 mortality projection tool will be produced in early January 2021, and will include any end-of-year revisions to mortality estimates from 2020 that are used as a basis for projection in 2021.

ADDITIONAL INFORMATION

A more detailed description of the data sources and stock assessment results will be available on the IPHC's website stock assessment page prior to the 97th Session of the IPHC's Annual Meeting (AM097). That page also includes recent peer review documents and previous stock assessment documents. Further, the IPHC's website contains many interactive tools for both FISS and commercial fishery information, as well as historical data series that replace appendices and tables from previous year's documents.

RECOMMENDATION/S

That the Commission:

a) **NOTE** paper IPHC-2021-AM097-08 which provides a summary of data, the 2020 stock assessment and the harvest decision table for 2021.

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