Summary of the data, stock assessment, and harvest decision table for Pacific halibut (*Hippoglossus stenolepis*) at the end of 2021

PREPARED BY: IPHC SECRETARIAT (I. STEWART, A. HICKS, R. WEBSTER, D. WILSON, AND B. HUTNICZAK; 13 OCTOBER & 23 NOVEMBER 2021)

PURPOSE

To provide the Commission with a summary of the data, stock assessment, and harvest decision table at the end of 2021.

INTRODUCTION

In 2021 the International Pacific Halibut Commission (IPHC) undertook its annual coastwide stock assessment of Pacific halibut (*Hippoglossus stenolepis*). This assessment represents an update to the 2020 stock assessment (IPHC-2020-SA01), with incremental changes documented through a two-part review by the IPHC's Scientific Review Board (SRB; IPHC-2021-SRB018-R, IPHC-2021-SRB019-R). Changes and new data for 2021 include:

1. Update the version of the stock synthesis software (Methot and Wetzel 2013) used for the analysis (3.30.17).
2. New modelled trend information from the 2021 IPHC's FISS (fishery-independent setline survey), including estimates covering the entire 1890 station design and all IPHC Regulatory Areas.
3. Age, length, individual weight, and average weight-at-age estimates from the 2021 FISS for all IPHC Regulatory Areas.
4. 2021 (and a small amount of 2020) Commercial fishery logbook trend information from all IPHC Regulatory Areas.
5. 2021 Commercial fishery biological sampling (age, length, individual weight, and average weight-at-age) from all IPHC Regulatory Areas. Sex-ratios-at-age for the 2020 commercial fishery (building on the 2017-2019 sex-ratios used in the 2020 stock assessment).
6. Biological information (lengths and/or ages) from non-directed discards (IPHC Regulatory Areas where available) and the recreational fishery (IPHC Regulatory Area 3A only) from 2020.
7. Updated mortality estimates for 2020 (where preliminary values were used) and estimates for all sources in 2021.

This document provides an overview of the final data sources available for the 2021 Pacific halibut stock assessment including the population trends and distribution among IPHC Regulatory Areas based on the modelled IPHC fishery-independent setline survey (FISS), directed commercial fishery data, and results of the stock assessment.

Overall, model results remain highly consistent with those of recent stock assessments. Spawning biomass trends continue slightly downward, although the 2021 assessment reports less decline than projected, partly due to estimated mortality below that associated with limits set for 2021. The 2012 year-class, estimated to be stronger than any since 2005, is critically important to short-term projections of stock and fishery dynamics.

STOCK AND MANAGEMENT

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

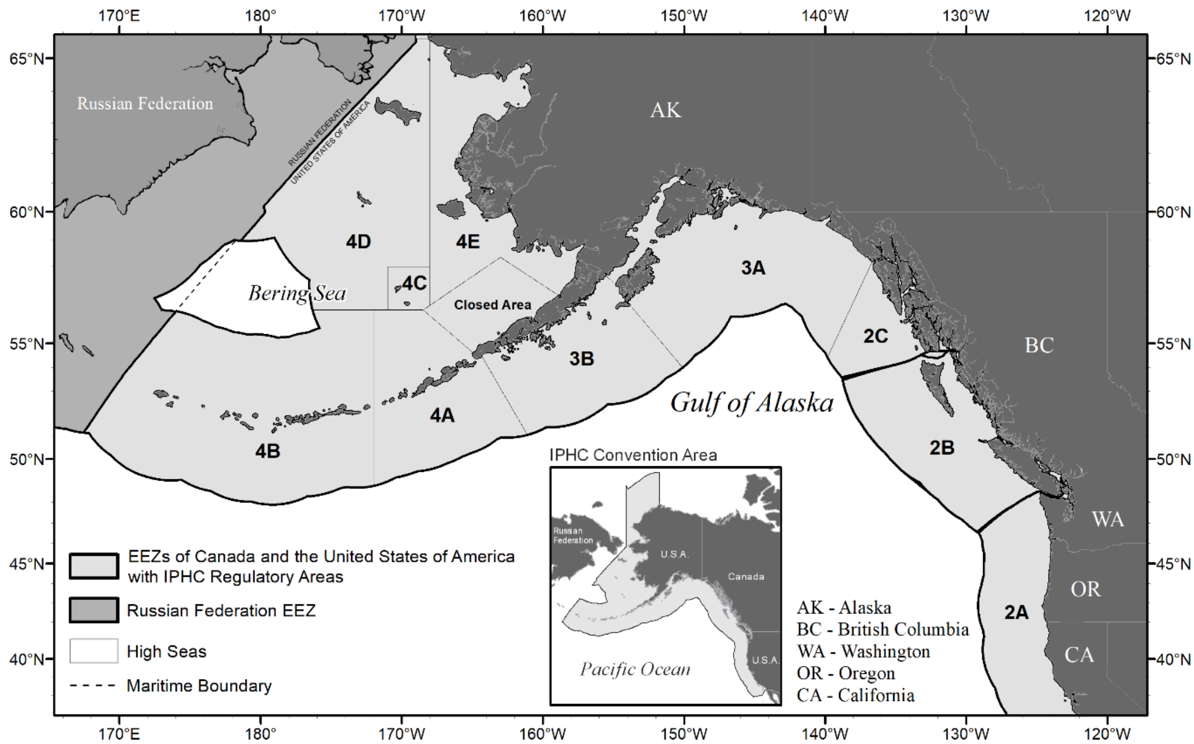

FIGURE 1. IPHC Convention Area (insert) and IPHC Regulatory Areas.

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) will be provided in early January 2022 for exploration via the IPHC's mortality projection tool (IPHC-2021-IM097-INF02).

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 prohibited). Over the period 1888-2021 mortality has totaled 7.3 billion pounds (~3.3 million metric tons, t). Since 1922, the fishery has ranged annually from 34 to 100 million pounds

[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.

(15,000-45,000 t) with an annual average of 63 million pounds (~29,000 t; Figure 2). Annual mortality was above this 100-year average from 1985 through 2010 and has averaged 38.5 million pounds (~17,500 t) from 2017-21.

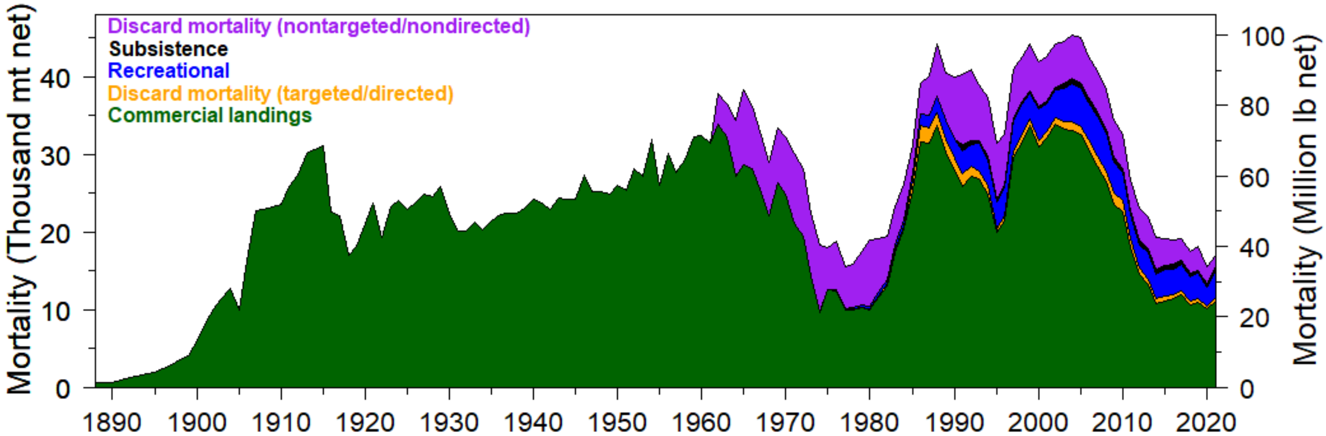

FIGURE 2. Summary of estimated historical mortality by source (colors), 1888-2021.

2021 Fishery and IPHC FISS statistics

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). The assessment data from both fishery dependent and fishery independent sources, as well as auxiliary biological information, are most spatially complete since the late-1990s. Primary sources of information for this assessment include mortality estimates from all sources (IPHC-2021-IM097-06), modelled indices of abundance (IPHC-2021-IM097-08 Rev_1) based on the IPHC's 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).

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 2021, the most important information came from the modelled index of abundance reflecting the extensive 2021 FISS and associated biological sampling. Routine updates of logbook records from the 2021 (and earlier) directed commercial fishery, as well as age-frequency observations and individual weights from the commercial fishery were also included. Directed commercial fishery sex-ratios at age were available for 2020 (building on the genetic data for 2017-2019 previously available). Beginning in 2019, individual weights have been collected during FISS operations such that WPUE (weight per unit effort) 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 2021. All available information was finalized on 1 November 2021 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).

Coastwide commercial Pacific halibut fishery landings (including research landings) in 2021 were approximately 24.5 million pounds (~11,100 t), up 9% from 2020[2]. Discard mortality in non-directed fisheries was estimated to be 3.5 million pounds in 2021 (~1,600 t)[3], down 23% from 2020 and representing the smallest estimate in the time-series. The total recreational mortality (including estimates of discard mortality) was estimated to be 7.6 million pounds (~3,470 t) up 43% from reduced fisheries that occurred in 2020. Mortality from all sources increased by 10% to an estimated 37.7 million pounds (~17,100 t) in 2021 based on preliminary information available through 1 November 2021.

The 2021 modelled FISS results detailed a coastwide aggregate NPUE (numbers per unit effort) which increased by 17% from 2020 to 2021, reversing the declines observed over the last four years (Figure 3). Biological Region 3 increased by 28%, while Biological Region 2 increased by 15%. Biological Regions 4, and 4B (sampled as planned in 2021 after the curtailed survey in 2021) both showed small declines (3 and 2%) and are at or near the lowest values in the estimated time-series. The 2021 modelled coastwide WPUE of legal (O32) Pacific halibut, the most comparable metric to observed commercial fishery catch rates, increased by 4% from 2020 to 2021. This reduced trend relative to that for NPUE indicates that recruitment of younger fish is contributing more to current stock productivity than somatic growth of fish already over the legal minimum size limit. Individual IPHC Regulatory Areas varied from a 57% increase (Regulatory Area 3B) to a 9% decrease (Regulatory Area 4CDE; Figure 4) in O32 WPUE. Due to the extensive survey conducted in 2021, uncertainty was near or below historical levels for most IPHC Regulatory Areas in 2021.

[2] The mortality estimates reported in this document are those available on 1 November 2021 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 2022 and will be incorporated into final projections for 2022.

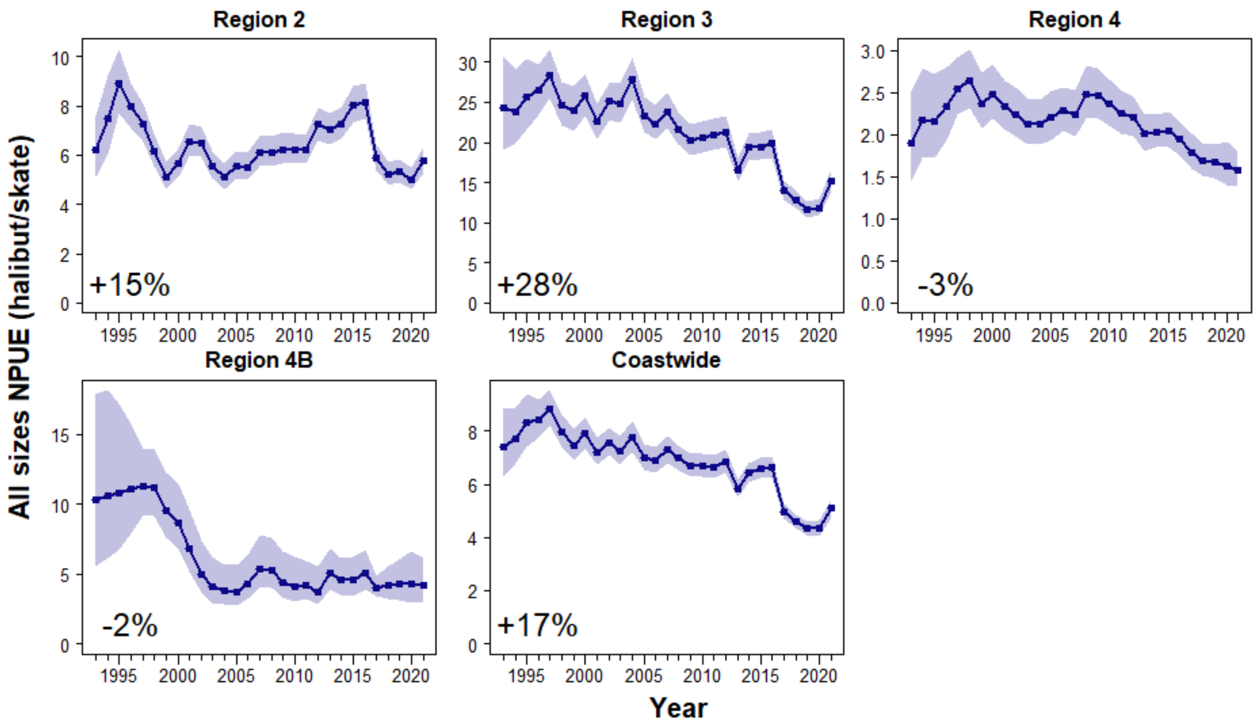

FIGURE 3. Trends in modelled FISS NPUE by Biological Region, 1993-2021. Percentages indicate the change from 2020 to 2021. Shaded zones indicate 95% credible intervals.

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 (+/- 0%) coastwide. Trends varied among IPHC Regulatory Areas and gears; however, Area-specific trends were mixed, and generally similar to those from the FISS, with the exception of IPHC Regulatory Area 4A which showed a sharp increase in the commercial data.

Biological information (ages and lengths) from the commercial fishery landings continue to show the 2005 year-class as the largest coastwide contributor (in number) to the fish encountered, with the 2012 year-class nearly as abundant. The FISS observed the 2012 cohort (9 years old) at the largest proportion in the total catch of any age class for the first time. Observation of these fish both above and below the commercial fishery minimum size limit indicates their increasing importance to the stock and to future fisheries. Individual size-at-age appears to be increasing for younger ages (<14) in most IPHC Regulatory Areas and coastwide. Although size-at-age changes slowly, if the current pattern persists into older ages, it could have large implications for overall yield.

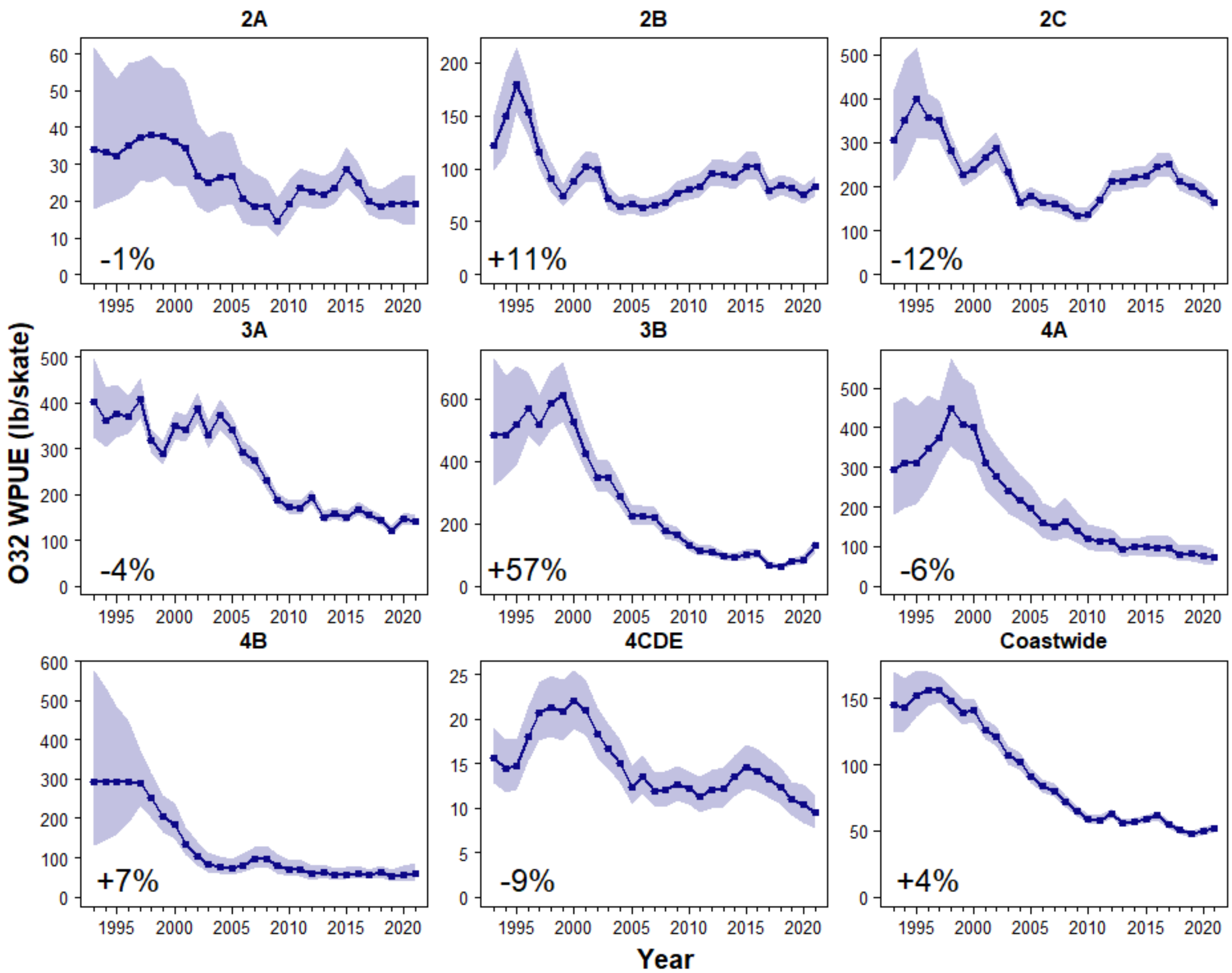

FIGURE 4. Trends in modelled FISS legal (O32) WPUE by IPHC Regulatory Area, 1993-2021. Percentages indicate the change from 2020 to 2021. Shaded zones indicate 95% credible intervals.

Biological stock distribution

The current trend in population distribution (measured via the modelled FISS catch in weight of all Pacific halibut) appears to be shifting back toward Biological Region 3 after more than a decade of decline. In both 2020 and 2021, Biological Regions 2 and 4 have decreased, while Region 4B has stayed relatively constant (Figure 6; recent years in Table 1). 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.

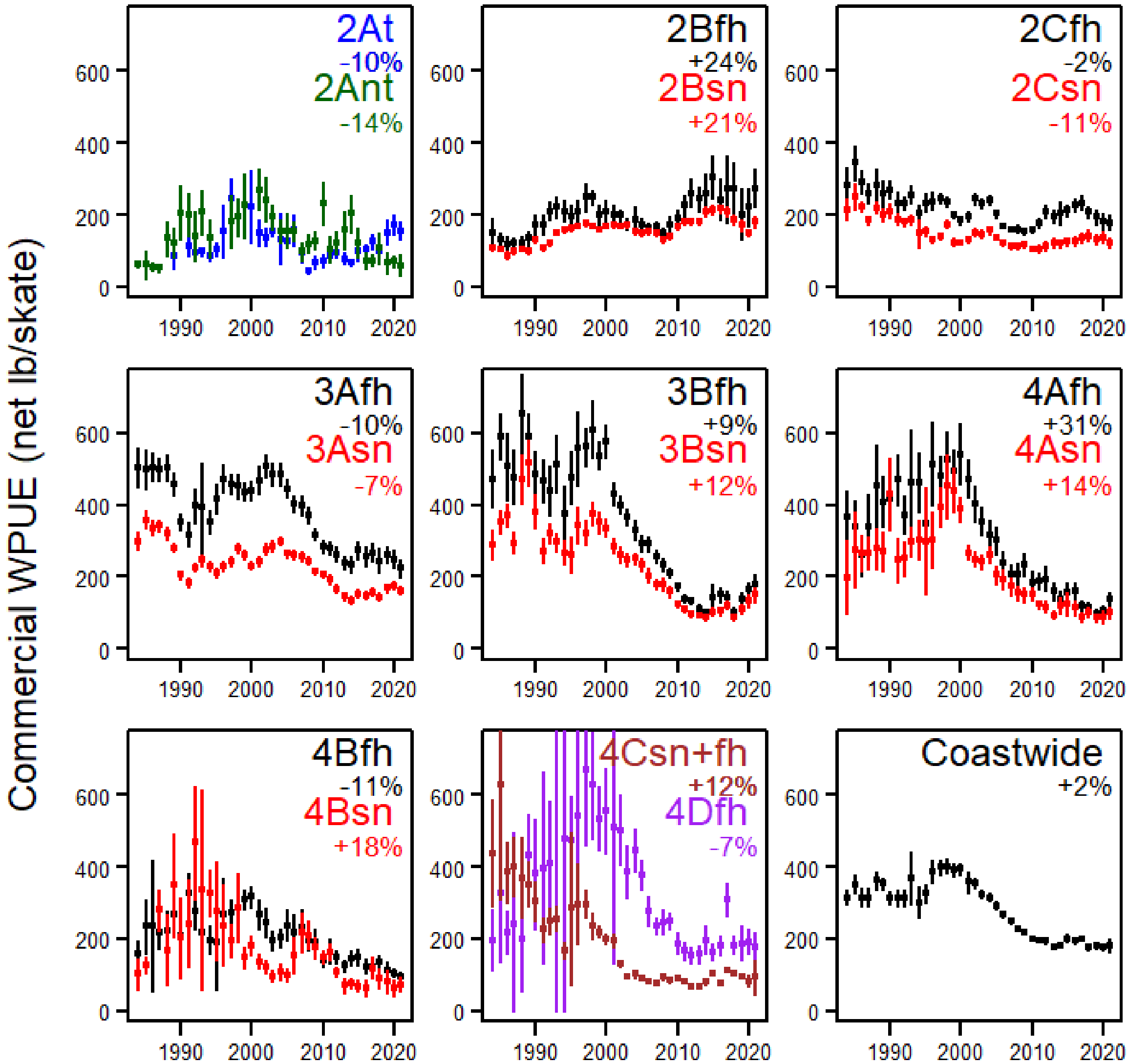

FIGURE 5. Trends in commercial fishery WPUE by IPHC Regulatory Area and fishery or gear, 1984-2021. The tribal fishery in 2A is denoted by “2At”, non-tribal by “2Ant”, fixed hook catch rates by “fh” and snap gear catch rates by “sn” for IPHC Regulatory Areas 2B-4D. Percentages indicate the change from 2020 to 2021 uncorrected for bias due to incomplete logbooks (see text above). Vertical lines indicate approximate 95% confidence intervals.

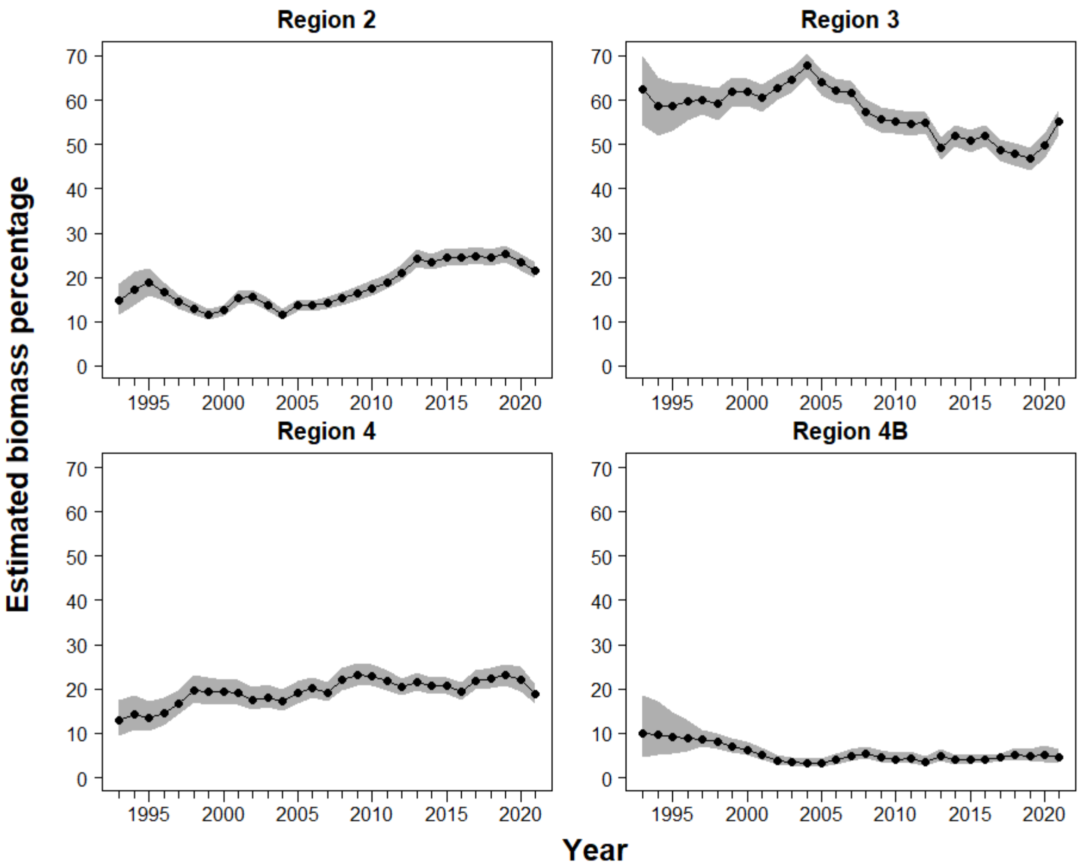

FIGURE 6. Estimated stock distribution (1993-2021) based on modelled survey catch weight of all sizes of Pacific halibut. Shaded zones indicate 95% credible intervals.

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
2017	24.5%	48.3%	22.6%	4.6%
2018	24.1%	47.6%	22.9%	5.4%
2019	24.9%	46.3%	23.8%	5.0%
2020	23.0%	49.4%	22.6%	5.1%
2021	21.3%	54.8%	19.2%	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 for all regions are available. 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 represented 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. The 2021 assessment again updates the same model structure with new data; incremental changes were again documented through a two-part review by the IPHC's scientific review process (IPHC-2021-SRB018-R, IPHC-2021-SRB019-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 2021 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 191 million pounds (~86,600 t) at the beginning of 2022, with an approximate 95% credible interval ranging from 129 to 277 million pounds (~58,700-125,400 t; Figure 8). The recent spawning biomass estimates from the 2021 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 (71 and 72% for the coastwide and AAF models respectively) during favorable Pacific Decadal Oscillation (PDO) regimes, a widely recognized indicator of ecosystem productivity in the north Pacific (primarily the Gulf of Alaska). 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 and 2021 (through September) showing negative average conditions. Although strongly correlated with historical recruitments, it is unclear whether recent conditions are comparable to those observed in previous decades.

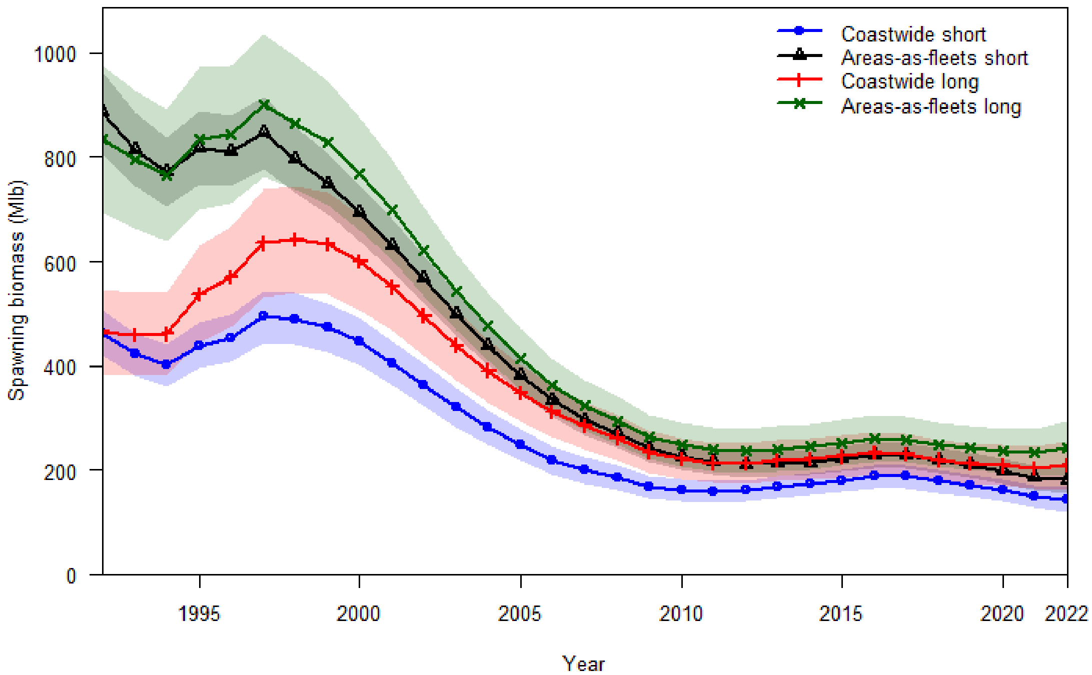

FIGURE 7. Estimated spawning biomass trends (1992-2022) based on the four individual models included in the 2021 stock assessment ensemble. Series indicate the maximum likelihood estimates; shaded intervals indicate approximate 95% credible intervals.

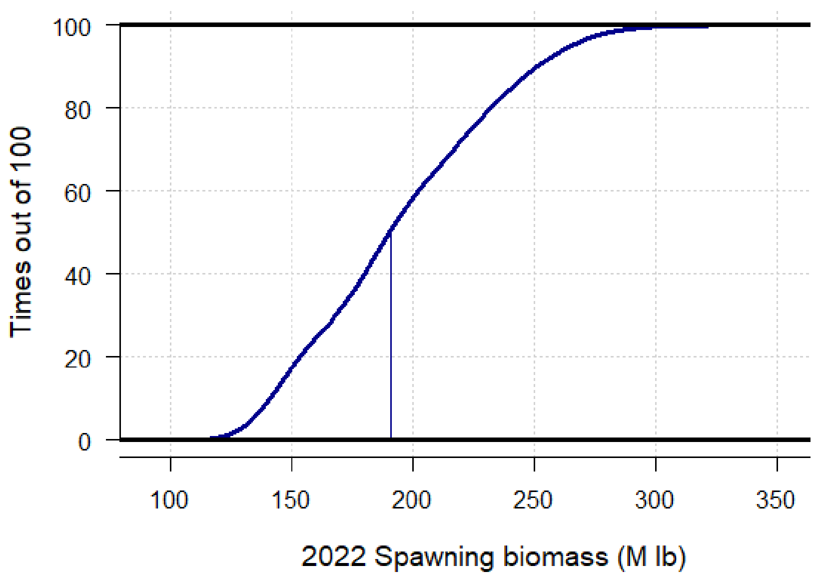

FIGURE 8. Cumulative distribution of the estimated spawning biomass at the beginning of 2022. Curve represents the estimated probability that the biomass is less than or equal to the value on the x-axis; vertical line represents the median (191 million pounds, ~86,600 t).

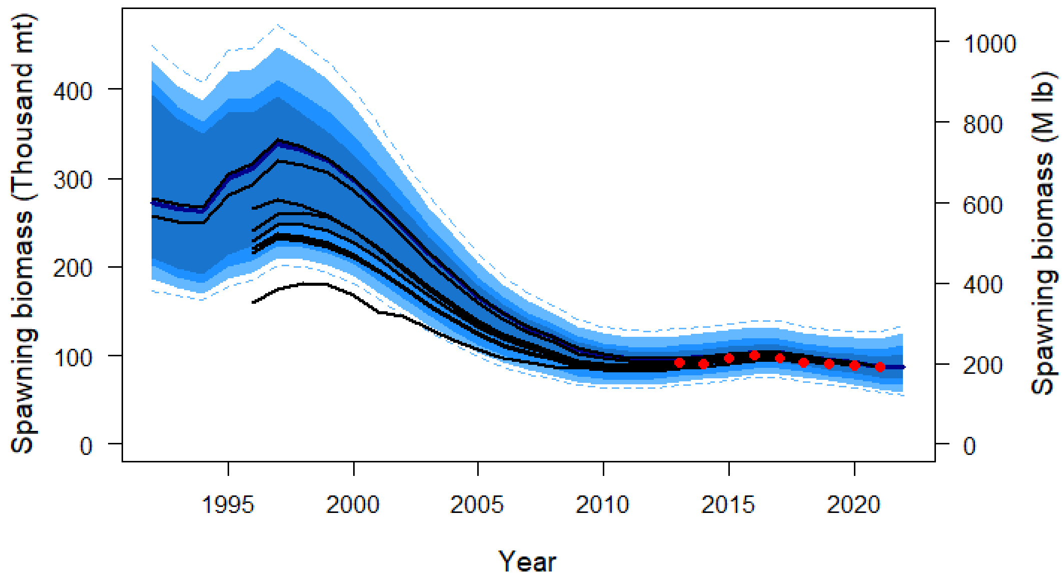

FIGURE 9. Retrospective comparison among recent IPHC stock assessments. Black lines indicate estimates of spawning biomass from assessments conducted in 2012-2020 with the terminal estimate shown as a red point. The shaded distribution denotes the 2021 ensemble: the dark blue line indicates the median (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 recent large cohorts in 1999 and 2005 (Figure 10). Cohorts from 2006 through 2011 are estimated to be much smaller than those from 1999-2005, which has resulted in a decline in both the stock and fishery yield as these low recruitments have moved into the spawning biomass. Based on age data through 2021, individual models in this assessment produced estimates of the 2012 year-classes that are comparable to the magnitude of the 2005 year-class. The 2012 year-class is estimated to be 19% mature in 2021, and the maturation of this cohort has a strong effect on the short-term projections.

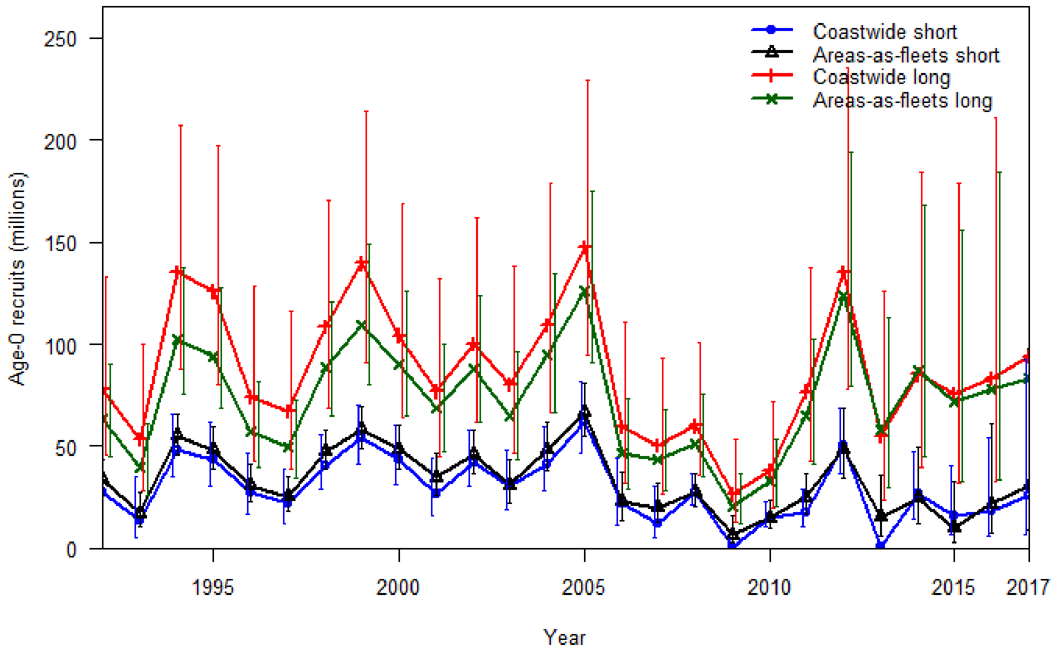

FIGURE 10. Estimated age-0 recruitment trends (1992-2017) based on the four individual models included in the 2021 stock assessment ensemble. Series indicate the maximum likelihood estimates; vertical lines indicate approximate 95% credible intervals.

The IPHC's interim management procedure uses a relative spawning biomass of 30% as a trigger, below which the reference fishing intensity is reduced. At a spawning biomass limit of 20%, directed fishing is halted due to the critically low biomass condition. This calculation is based on recent biological conditions: current weight-at-age and estimated recruitments still influencing the stock. Thus, the 'dynamic' calculation measures only the effect of fishing on the spawning biomass. The relative spawning biomass in 2022 was estimated to be 33% (credible interval: 22-54%) equal to the estimate from 2020, and greater than the values estimated for the previous decade. The probability that the stock is below the $SB_{30\%}$ level is estimated to be 45% at the beginning of 2022, 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 (57%), and the coastwide model above (225%). 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 interim management procedure specifies a reference 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. The 2021 fishing intensity is estimated to correspond to $F_{46\%}$ (credible interval: 35-63%; Table 2). Both 2020 and 2021 are estimated to be less than values estimated for the last 20+ years. This drop in fishing intensity corresponds both to reduced mortality limits (2020) and actual mortality below the limits (2020 and 2021). Comparing the relative spawning biomass and fishing intensity over the recent historical period 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).

BIO-SOCIOECONOMIC TRENDS

New for the 2021 assessment, the bio-socioeconomic conditions for the Pacific halibut fishery are described via an index of the relative price, costs (fuel and wages) and stock condition (see IPHC-2021-IM097-INF03 for additional details). The index value increased from 2020 to 2021 and is now 23% above the last 10-year average, reflecting relatively favorable conditions (Table 2). This increase was mainly driven by higher fish prices that recovered faster than fuel prices from the depressed values observed in 2020, and to some degree lower labor costs; the higher observed WPUE in 2021 had very little impact on the index (Figure 12).

TABLE 2. Status summary of Pacific halibut in the IPHC Convention Area at beginning of 2022.

Indicators	Values	Trends	Status
Total mortality 2021: Percent retained 2021: Average mortality 2017–21:	37.66 MLBS, 17,084 T[1] 88% 38.48 MLBS, 17,456 T	MORTALITY INCREASED FROM 2020 TO 2021	**2021 MORTALITY NEAR 100-YEAR LOW**
SPR_{2021}: P(SPR<43%): P(SPR<limit):	46% (35-63%)[2] 47% LIMIT NOT SPECIFIED	FISHING INTENSITY INCREASED FROM 2020 TO 2021	**FISHING INTENSITY BELOW REFERENCE LEVEL[3]**
SB_{2022} (MLBS): SB_{2022}/SB_0: $P(SB_{2022}<SB_{30})$: $P(SB_{2022}<SB_{20})$:	191 (129–277) MLBS 33% (22-54%) 45% <1%	SB DECREASED 17% FROM 2016 TO 2022	**NOT OVERFISHED[4]**
Biological stock distribution:	SEE TABLES AND FIGURES	REGION 3 INCREASING	**WITHIN HISTORICAL RANGES**
Bio-socioeconomic conditions	23% ABOVE 10-YEAR AVERAGE	INCREASED FROM 2020 TO 2021	**FAVORABLE[5]**

[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 $SB_{20\%}$.
[5] Status determined relative to the most recent 10-year (2011-2020) average.

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.

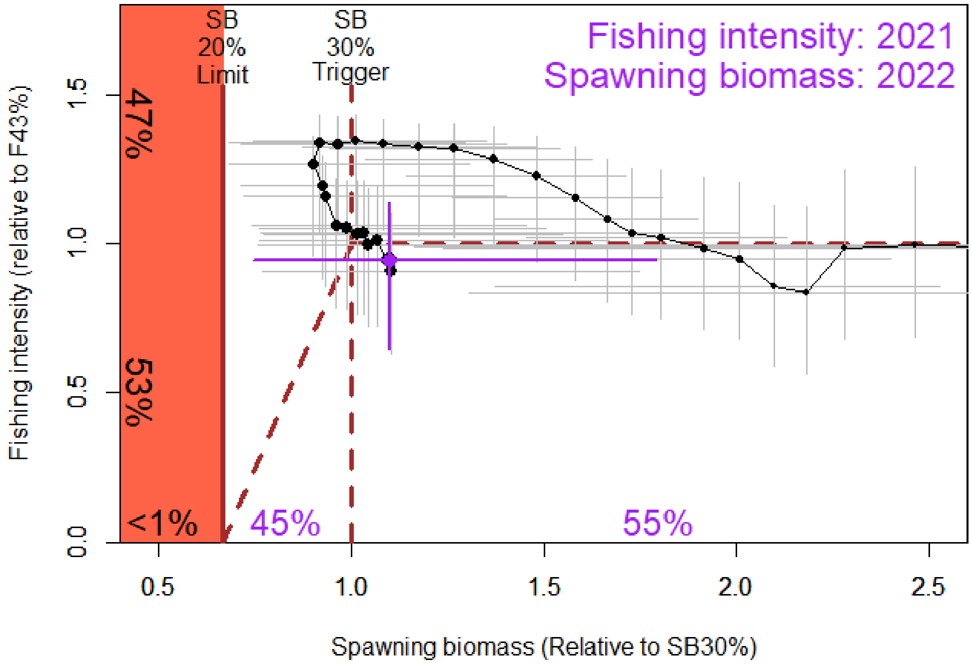

FIGURE 11. Phase plot showing the time-series (1992-2022) of estimated spawning biomass and fishing intensity relative to the reference points specified in the IPHC's interim management procedure. Dashed lines indicate the current $F_{43\%}$ (horizontal) reference fishing intensity, with linear reduction 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 2021 and spawning biomass at the beginning of 2022 shown as the largest point (purple). Percentages along the y-axis indicate the probability of being above and below $F_{43\%}$ in 2021; 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 2022.

The assessment utilized four years (2017-20) of sex-ratio information from the directed commercial fishery landings. However, uncertainty in historical ratios 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. 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 in 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.

Additional important contributors to assessment uncertainty (and potential bias) include the lag in estimation of incoming recruitment between birth year and direct observation in the fishery and survey data (6-10 years). Like most stock assessments, there is no direct information on natural mortality, and increased uncertainty for some estimated components of the fishery mortality. Fishery mortality estimates are assumed to be accurate; therefore, uncertainty due to discard mortality estimation (observer sampling and representativeness), discard mortality rates, and any other documented mortality in either directed or non-directed fisheries (e.g., whale depredation) could create bias in this assessment. Maturation schedules and fecundity 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 trends in these biological processes at the scale of the entire population. Projections beyond three years are avoided due to the lack of mechanistic understanding of the factors influencing size-at-age and relative recruitment strength, the two most important factors in historical population trends.

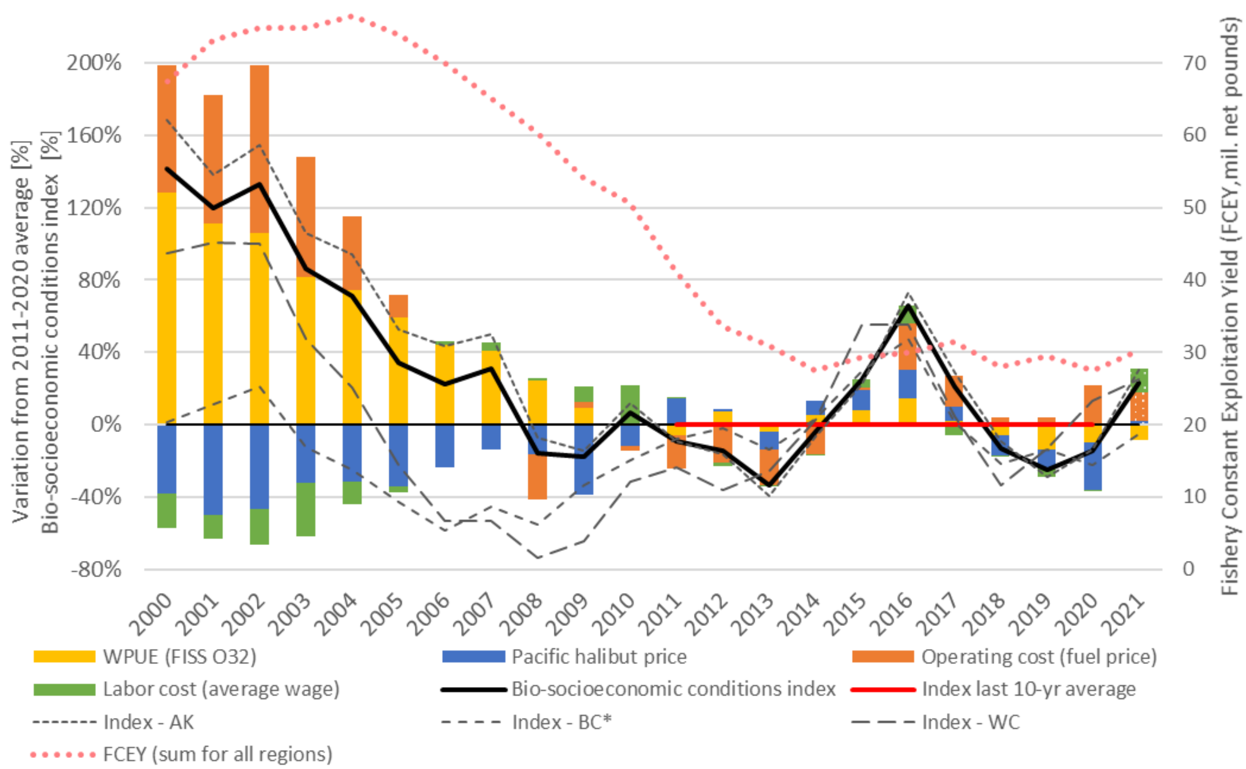

FIGURE 12. Bio-socioeconomic index for Pacific halibut fisheries (2000-2021). Thick black line denotes the annual index, stacked bars denote the contributing components, dashed lines show the regional indices, and the dotted line reports the coastwide FCEY (mortality limit for the directed fisheries) on the second axis. See IPHC-2021-IM097-INF03 for additional details.

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 ongoing Management Strategy Evaluation (MSE) process can inform the development 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 2021 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 2022 (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) include several levels of mortality intended for evaluation of stock and management procedure dynamics including:

- No fishing mortality (useful to evaluate the stock trend due solely to population processes)
- A 30 million pound (~13,600 t) 2022 TCEY
- The mortality at which there is a 50% chance that the spawning biomass will be smaller in three years than in 2022 ("*3-year surplus*")
- The mortality consistent with repeating the TCEY set for 2021 (39.0 million pounds, 17,690 t; *"status quo"*).
- The mortality consistent with the current "Reference" SPR ($F_{43\%}$) level.
- A 60 million pound (~27,200 t) 2022 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 column of the decision table, the total fishing mortality (including all sizes and sources), the coastwide TCEY and the associated level of fishing intensity projected for 2022 (median value with the 95% credible interval below) are reported.

The projections for this assessment are more optimistic than those from the 2019 and 2020 assessments due to the increasing projected maturity of the 2012 year-class. This translates to a lower probability of stock decline for 2022 than in recent assessments as well as a decrease in this probability through 2023-24. There is greater than a 50% probability of stock decline in 2023 (55-64/100) for the entire range of SPR values from 40-46%, which include the *status quo* TCEY and the $F_{43\%}$ reference level. The 2022 "3-year surplus" alternative, corresponds to a TCEY of 38.0 million pounds (~17,240 t), and a projected SPR of 48% (credible interval 32-63%; Table 3, Figure 12). At the reference level (a projected SPR of 43%), the probability of spawning biomass decline from 2022 to 2023 is 59%, decreasing to 55% in three years, as the 2012 cohort matures. The one-year risk of the stock dropping below $SB_{30\%}$ ranges from 43% at the $F_{46\%}$ level to 45% at the at the $F_{40\%}$ level of fishing intensity.

TABLE 3. Harvest decision table for 2022 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.

		2022 Alternative				3-Year Surplus		*Status quo*		*Reference* $F_{43\%}$					
		Total mortality (M lb)	0.0	31.2	38.7	39.2	39.9	40.2	41.1	42.4	43.8	45.2	46.6	61.2	
		TCEY (M lb)	0.0	30.0	37.5	38.0	38.7	39.0	39.9	41.2	42.6	44.0	45.4	60.0	
		2022 fishing intensity	$F_{100\%}$	$F_{53\%}$	$F_{46\%}$	$F_{46\%}$	$F_{45\%}$	$F_{45\%}$	$F_{44\%}$	$F_{43\%}$	$F_{42\%}$	$F_{41\%}$	$F_{40\%}$	$F_{32\%}$	
		Fishing intensity interval	--	38-69%	32-64%	32-63%	32-63%	31-63%	31-62%	30-61%	29-60%	28-59%	28-59%	21-51%	
Stock Trend (spawning biomass)	in 2023	is less than 2022	<1	39	55	55	56	57	58	59	61	63	64	84	a
		is 5% less than 2022	<1	3	14	16	18	19	21	25	30	34	37	58	b
	in 2024	is less than 2022	<1	39	53	54	55	55	56	58	59	61	62	80	c
		is 5% less than 2022	<1	16	37	39	40	41	43	46	48	50	52	66	d
	in 2025	is less than 2022	<1	33	49	50	51	52	53	55	56	58	60	77	e
		is 5% less than 2022	<1	18	38	39	41	42	43	46	48	50	52	67	f
Stock Status (Spawning biomass)	in 2023	is less than 30%	31	40	43	43	43	43	44	44	44	45	45	48	g
		is less than 20%	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	h
	in 2024	is less than 30%	16	34	39	39	40	40	41	41	42	43	44	49	i
		is less than 20%	<1	<1	<1	<1	<1	1	1	1	1	1	1	6	j
	in 2025	is less than 30%	4	29	36	37	37	37	38	40	41	42	43	49	k
		is less than 20%	<1	<1	1	1	1	1	1	1	2	2	3	12	l
Fishery Trend (TCEY)	in 2023	is less than 2022	0	21	48	49	49	49	50	50	50	50	51	70	m
		is 10% less than 2022	0	7	41	42	44	45	47	48	49	50	50	58	n
	in 2024	is less than 2022	0	22	48	48	49	49	50	50	50	50	50	69	o
		is 10% less than 2022	0	9	41	42	44	45	46	48	49	50	50	58	p
	in 2025	is less than 2022	0	22	47	48	48	49	49	50	50	50	50	68	q
		is 10% less than 2022	0	10	40	42	43	44	46	48	49	49	50	58	r
Fishery Status (Fishing intensity)	in 2022	is above $F_{43\%}$	0	20	48	49	49	50	50	50	50	50	51	70	s

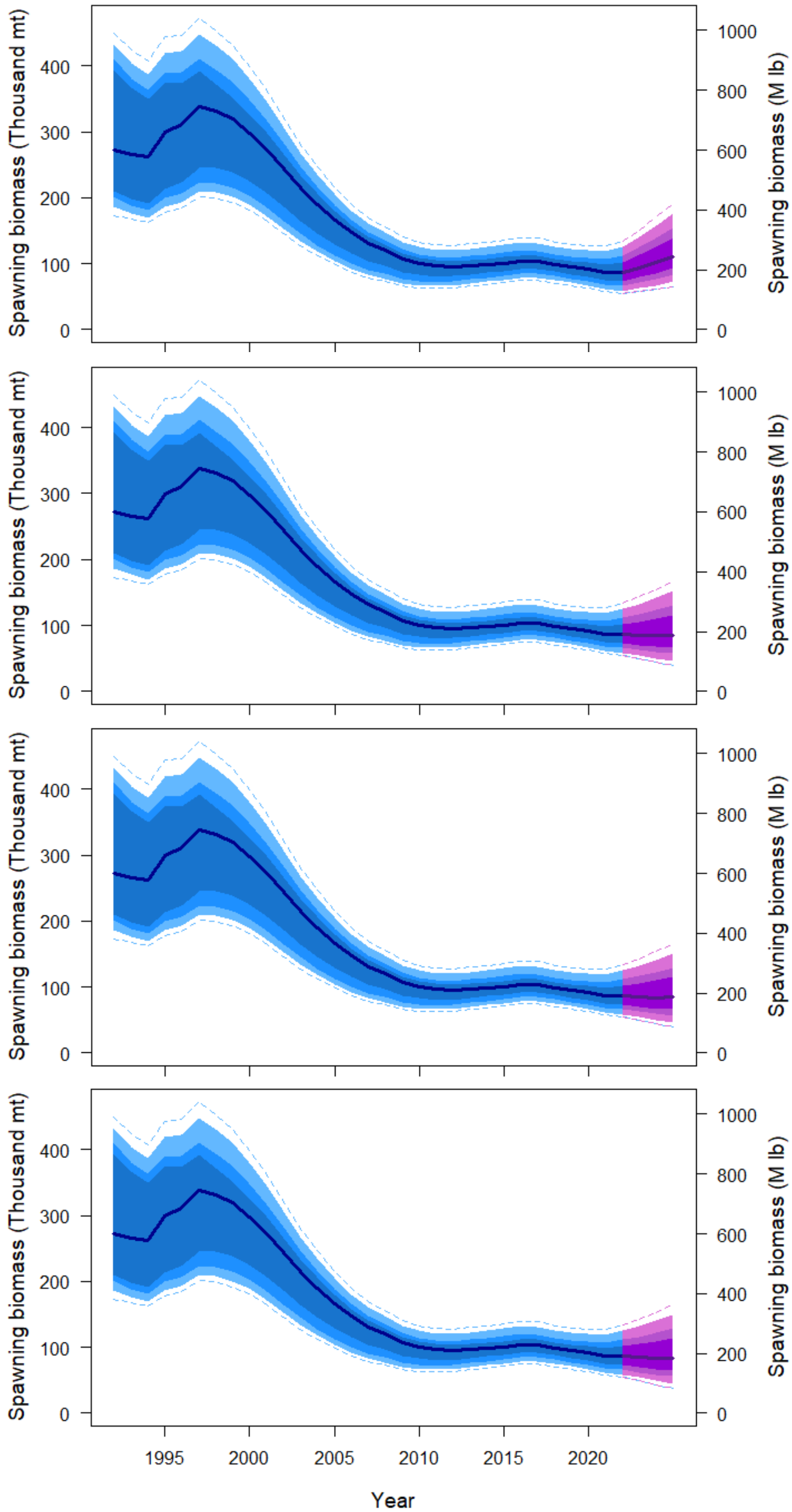

FIGURE 13. Three-year projections of stock trend under alternative levels of mortality: no fishing mortality (upper panel), the 3-year surplus (a TCEY of 38.0 million pounds, ~17,240 t; second panel), the *status quo* TCEY set in 2021 of 39.0 million pounds, 17,690 t; third panel), and the TCEY projected for the IPHC's interim management procedure (41.2 million pounds, 18,700 t; lower panel).

SCIENTIFIC ADVICE

Sources of mortality: In 2021, total Pacific mortality due to fishing increased to 37.66 million pounds (17,084 t) but remained below the 5-year average of 38.48 million pounds (17,456 t). Of that total, 88% comprised the retained catch (Table 2), up from 84% in 2020.

Fishing intensity: The 2021 fishing mortality corresponded to a point estimate of SPR = 46%; there is a 47% chance that fishing intensity exceeded the IPHC's current reference level of $F_{43\%}$ (Table 2). The Commission does not currently have a coastwide fishing intensity limit reference point.

Stock status (spawning biomass): Current (beginning of 2022) female spawning biomass is estimated to be 191 million pounds (86,600 t), which corresponds to an 45% 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 increased sharply over 2020-21, reversing over a decade of steady decline (Figure 6,Table 1). This trend occurs in tandem with declines in Biological Regions 2 and 4; however, all regions remain within the historical range observed from 1993-2021. These estimates have been updated and strongly informed by the comprehensive FISS design implemented in 2021 (IPHC-2021-IM097-07).

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 5-year research plan (IPHC-2021-IM097-12).

DETAILED MANAGEMENT INFORMATION

The IPHC's 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 uses 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-IM097-INF02. The 2022 mortality projection tool will be produced in early January 2022, and will include any end-of-year revisions to mortality estimates from 2021 that are used as a basis for projections.

ADDITIONAL INFORMATION

Detailed material for AM098 will include any revisions to this summary document. As in 2020, a more detailed description of the stock assessment (IPHC-2022-SA-01) and the data sources

(IPHC-2022-SA-02), will be published directly to the stock assessment page on the IPHC's website. 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-IM097-10 Rev_1 which provides a summary of data, the 2021 stock assessment and the harvest decision table for 2022.

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