Assessment of the Pacific halibut (*Hippoglossus stenolepis*) stock at the end of 2023

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PURPOSE

To provide the Commission with a detailed report of the 2023 stock assessment analysis.

EXECUTIVE SUMMARY

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 2023. A summary of the data and assessment results, as well as stock projections and the harvest decision table are provided both on the stock assessment webpage and in the meeting materials for the IPHC's 100th Annual Meeting (AM100; IPHC-2024-AM100-10; IPHC-2024-AM100-12). The input data files for each model included in this stock assessment are available on the IPHC's stock assessment webpage.

A detailed overview of data sources is provided in a separate document (IPHC-2024-SA-02); only a few key observations are described here. Fishing mortality from all sources in 2023 was estimated to be down 7% from 2022. 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 2023 modelled Fishery-Independent Setline Survey (FISS; see IPHC-2024-AM100-08 and IPHC-2024-AM100-09) detailed a coastwide aggregate Numbers-Per-Unit-Effort (NPUE) which decreased by 2% from 2022 to 2023. The modelled coastwide FISS Weight-Per-Unit-Effort (WPUE) of legal (O32) Pacific halibut, the most comparable metric to observed commercial fishery catch rates, decreased by 3% from 2022 to 2023. Preliminary coastwide commercial fishery WPUE (based on all 2023 logbook records available for this assessment) decreased 10% coastwide. Biological information (ages and lengths) from both the commercial fishery and FISS shows a second year of the shift from the previously dominant 2005 year-class to the 2012 cohort (11 years old in 2023), representing the largest abundance at any single age. At the coastwide level, individual size-at-age continues on a flat or increasing trend across the age range most important to the directed fisheries, depending on the IPHC Regulatory Area.

This stock assessment is implemented using the generalized Stock Synthesis software (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 geographic regions. This combination of models includes uncertainty in the form of alternative hypotheses about several important axes of uncertainty, including: natural mortality rates (estimated in all models except the short coastwide time-series model), environmental effects on recruitment (estimated in the long time-series models), and other model parameters. 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.

This stock assessment represents an update, following the full assessment conducted in 2022 (IPHC-2023-SA01). There are no structural changes to the assessment methods for 2023. Supporting analyses were reviewed by the IPHC's Scientific Review Board (SRB) in June

(SRB022; IPHC-2023-SRB022-08, IPHC-2023-SRB022-R) and September 2023 (SRB023; IPHC-2023-SRB023-06, IPHC-2023-SRB023-R). All data sources that were preliminary in the 2022 stock assessment have been updated, along with the addition of all available data (as of 6 November) from 2023.

The results of the 2023 stock assessment indicate that the Pacific halibut stock declined continuously from the late 1990s to around 2012. 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 a low of 171 million pounds (~77,700 t) at the beginning of 2023. At the beginning of 2024, the spawning biomass is estimated to be 174 million pounds (78,900 t) with an approximate 95% credible interval ranging from 111 to 258 million pounds (~50,400-116,900 t). Spawning biomass estimates over the last few years of the time-series are slightly lower than recent stock assessment results. This change was found to be largely driven by the lower-than-expected commercial fishery catch-rates observed in 2023. Pacific halibut recruitment estimates show the large cohorts in 1999 and 2005. Cohorts from 2006 through 2011 are estimated to be much smaller than those from 1999-2005, which has led to recent estimated declines in both the stock and fishery yield as these low recruitments have moved int the spawning biomass. Based on age data through 2023, individual models in this assessment produced estimates of the 2012 year-classes that were slightly lower than the magnitude of the 2005 year-class. The 2012 year-class is estimated to be 42% mature in 2023 and the continued maturation of this cohort has a strong effect on the short-term projections.

The most influential source of new information in this assessment was the directed commercial fishery logbook trend, including the 2023 estimate as well as an updated (and lower) estimate of the catch-rate in 2022. The addition of just this information resulted in an 11% decrease in the 2023 spawning biomass estimate, compared to that in the 2022 stock assessment. Although differences in trend between the FISS and commercial fishery are not uncommon in the historical time-series, the sensitivity of this year's assessment results highlights the importance of both time-series in estimating the stock size and trend.

The IPHC's interim management procedure uses a relative spawning biomass of 30% as a fishery trigger, reducing the reference fishing intensity if relative spawning biomass decreases further toward a limit reference point at 20%, where directed fishing is halted due to the critically low biomass condition. The relative spawning biomass at the beginning of 2024 was estimated to be 42% (credible interval: 20-56%), slightly higher than the estimate for 2023 (41%). The probability that the stock is below $SB_{30\%}$ is estimated to be 26% at the beginning of 2023, with a 1% chance that the stock is below $SB_{20\%}$. The IPHC's current 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. Based on the 2023 assessment, the 2023 fishing intensity is estimated to correspond to an $F_{52\%}$ (credible interval: 31-66%). 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 2023 directed fisheries and other sources of mortality. There is at least a 45% probability of stock decline in 2024 for all yields greater than the *status quo*. The 2024 "3-year surplus" alternative, corresponds to a TCEY of 39.1 million pounds (17,700 t), and a projected SPR of 49% (credible interval 28-64%). At the reference level (a projected SPR of 43%), the probability of spawning biomass decline from 2024 to 2025 is 74%, decreasing to 72% in three years. The one-year risk of the stock dropping below

$SB_{30\%}$ is 24-26% across all alternatives. Retrospective analyses for each of the four models, and a discussion of major 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 the Salish Sea, 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. Mortality limits for each of eight IPHC Regulatory Areas[1] 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 a separate document (IPHC-2024-SA-02) on the IPHC's stock assessment webpage. Results in this document include current model estimates of stock size and trend reflecting all available data. Specific management information is summarized via projections and 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) will be reported at the 100th Session of the IPHC Annual Meeting (AM100) in January 2024.

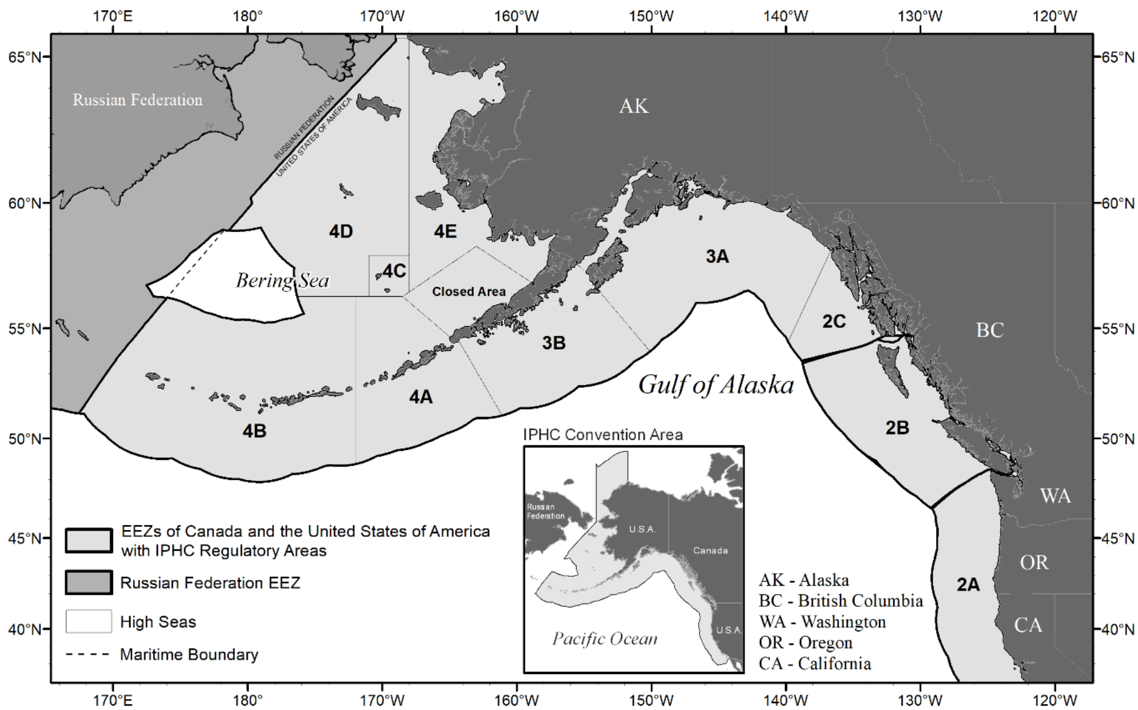

FIGURE 1. IPHC Convention Area (inset) and IPHC Regulatory Areas.

The IPHC's stock assessment and review process developed from the first *ad hoc* meeting held in 2012 (Stewart et al. 2013) to the formal SRB process including periodic external independent peer review. The IPHC's SRB meets two times per year: in June to review stock assessment development, and in September to review progress in response to the June review and to finalize

[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.

the model structure and methods to be used in conducting the year's stock assessment. Within this annual review process two types of stock assessments are produced: 1) updated assessments where new data are added but the methods and model structures remain largely unchanged, and 2) full stock assessments occurring approximately every three years in which model structure and methods are revised to reflect new data, approaches and comments from the SRB and independent review. The 2015 (Stewart and Martell 2016; Stewart et al. 2016), 2019 (Stewart and Hicks 2019; Stewart and Hicks 2020), and 2022 (Stewart and Hicks 2023) stock assessments (IPHC-2023-SA01) were full analyses. The 2023 stock assessment is an update, including routine extensions of existing data series and replacement of preliminary data from the 2022 analysis with final information available in 2023. There are no structural changes to the assessment methods for 2023. Supporting analyses were reviewed by the IPHC's SRB in June (SRB022; IPHC-2023-SRB022-08, IPHC-2023-SRB022-R) and September 2023 (SRB023; IPHC-2023-SRB023-06, IPHC-2023-SRB023-R).

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, 2015, 2019 and again in 2022. The largest change to the underlying data in 2022 was the development of a bootstrapping procedure to estimate the effective sample size of the age-composition data, given the actual sampling design and sample sizes in each year (Stewart and Hicks 2022). No major changes were made to the standard processing of data sources for 2023. Minor improvements included the use of West Coast Groundfish Observer Program estimates of directed non-tribal commercial discards in IPHC Regulatory Area 2A (IPHC-2024-SA-02). All available information for the 2023 stock assessment was finalized on 6 November 2023 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 2023 commercial fishery WPUE, 2023 commercial fishery age composition data, and 2023 mortality estimates for all fisheries still operating after 6 November. All preliminary data series in this analysis will be fully updated as part of the 2024 stock assessment.

Data for stock assessment use are initially compiled by IPHC Regulatory Area, and then aggregated to four Biological Regions: Region 2 (Areas 2A, 2B, and 2C), Region 3 (Areas 3A, 3B), Region 4 (4A, 4CDE) and Region 4B and then coastwide. In addition to the aggregate mortality (including all sizes of Pacific halibut), the assessment includes data from both fishery dependent and fishery independent sources as well as auxiliary biological information, with the most spatially complete data available since the late-1990s. Primary sources of information for this assessment include modelled indices of abundance (IPHC-2024-AM100-09); based on the FISS combined with other surveys (in numbers and weight), commercial fishery Catch-Per-Unit-Effort (weight), and biological summaries from both sources (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-2024-SA-02 on the IPHC's stock assessment webpage.

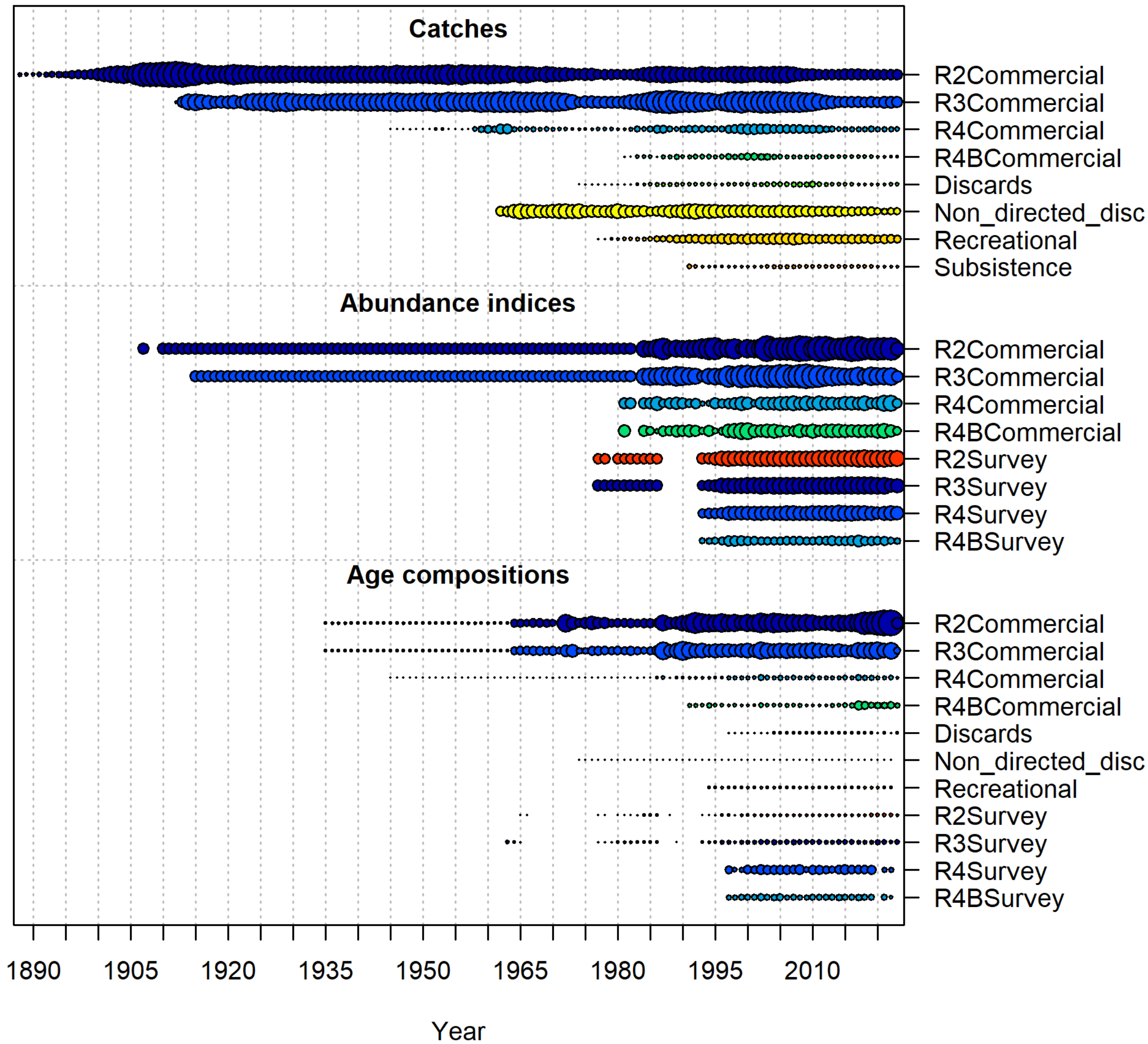

FIGURE 2. Overview of data sources. Circle areas are proportional to magnitude (mortality/catches) or the relative precision of the data (larger circles indicate greater precision for indices of abundance and age composition data).

Briefly, known Pacific halibut mortality consists of directed/targeted commercial fishery landings and discard mortality (including research), recreational fisheries, subsistence, and non-directed discard mortality (‘bycatch’) in fisheries targeting other species and where Pacific halibut retention is prohibited. Over the period 1888-2023 mortality has totaled 7.4 billion pounds (~3.3 million metric tons, t). Since 1923, the fishery has ranged annually from 34 to 100 million pounds (16,000-45,000 t) with an annual average of 63 million pounds (~29,000 t). Annual mortality was above this long-term average from 1985 through 2010 and has averaged 37.4 million pounds (~17,000 t) from 2019-23. Coastwide commercial Pacific halibut fishery landings (including research landings) in 2023 were approximately 23.0 million pounds (~10,400 t), down 6% from 2022. Discard mortality in the directed commercial fishery decreased 9% from 2022 to 2023 to 1.3 million pounds (~590 t) after a 37% increase in 2022. Discard mortality in non-directed fisheries was estimated to be 4.8 million pounds in 2023 (~2,200 t)[2], down 6% from 2022 and remaining below all recent estimates prior to 2019. The total recreational mortality (including estimates of discard mortality) in 2023 was estimated to be 6.0 million pounds (~2,700 t) down 4% from 2022. Mortality from all sources decreased by 7% to an estimated 35.9 million pounds (~16,300 t) in 2023 based on preliminary information available for this assessment.

The 2023 modelled FISS results detailed a coastwide aggregate NPUE (numbers per unit effort) which decreased by 2% from 2022 to 2023, remaining at levels similar to those observed in 2018-2020. Biological Region 3 decreased by 6%, while Biological Region 2 increased by 3% and Biological Region 4 remained unchanged. Biological Region 4B is estimated to have increased by 5%; however, this area was not sampled in 2023 and credible intervals are appreciably wider than in recent years, reflecting a wide plausible range of potential trends, both increasing and decreasing, from 2022 to 2023. The 2023 modelled coastwide Weight-Per-Unit-Effort (WPUE) of legal (O32) Pacific halibut, the most comparable metric to observed commercial fishery catch rates, decreased by 3% from 2022 to 2023. Individual IPHC Regulatory Areas varied from an estimated 10% increase (Regulatory Area 2A) to an 8% decrease (Regulatory Area 3B) in O32 WPUE. Preliminary commercial fishery WPUE estimates from 2023 logbooks decreased by 10% at the coastwide level. The bias correction to account for additional logbooks compiled after the fishing season resulted in an estimated decline of 12% coastwide. Trends varied among IPHC Regulatory Areas, fisheries, and gears; however, all areas showed decreased CPUE in one or more index. The drop in CPUE, larger than observed in the FISS results was influential in the overall stock assessment estimates (see sensitivity analysis below).

Biological information (ages and lengths) from the commercial fishery landings showed that in 2023 the 2012 year-class (now 11 years old) was again the largest coastwide contributor (in numbers) to the fish landed. This follows the same pattern observed in 2022, when the fishery transitioned from the previously most-abundant 2005 year-class. The FISS also observed the 2012 year-class as the largest proportion of the total catch of any cohort. There is no clear indication in the 2023 FISS data of a large abundance of year-classes younger than the 2012 cohort. Recent trawl surveys suggest the potential for one or more strong year-classes in 2017-2018; however, it will be several years before these fish can be confirmed in the FISS and directed fisheries. Individual size-at-age appears to be increasing for younger ages (<14) and was relatively stable for older fish 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. Direct estimates of the sex-ratio at age for the directed commercial fishery from 2022 (these data lag one year due to laboratory processing time) showed an average of 75% female (by number) in the landings, similar to 2021 (74%).

The population distribution (measured via the modelled FISS catch in weight of all Pacific halibut) showed a continued decrease in Biological Region 3 to the lowest proportion of the coastwide stock in the time-series. Biological Region 2 increased to the highest proportion observed. As there was no FISS sampling in Biological Region 4B, the credible intervals were very wide, consistent with either a decrease or increase in the proportion in this Region. Survey data are insufficient to estimate stock distribution prior to 1993. It is therefore unknown how historical distributions may compare with recent observations.

[2] The IPHC receives preliminary estimates of the current year's non-directed discard mortality from the NOAA Fisheries 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. For 2023, an ensemble of four stock assessment models was again used to describe the range of plausible current stock estimates. The ensemble approach recognizes that there is no “true” 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 Martell 2015; Stewart and Hicks 2018). 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; therefore providing a stronger basis for risk assessment.

This stock assessment is implemented using stock synthesis, the generalized stock assessment software (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 geographic regions (Areas-As-Fleets; AAF). 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 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.

This combination of models included a broad suite of structural and parameter uncertainties, including natural mortality rates (estimated in three of the four models and fixed in one model), 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 Hicks 2020; 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 truncated data series as well as little context for current dynamics.

Each of the four models in the ensemble was equally weighted, and within-model uncertainty from each model was propagated through to the ensemble results via the maximum likelihood estimates and an asymptotic approximation to their variance. Point estimates in this stock assessment correspond to median values from the ensemble with the simple probabilistic interpretation that there is an equal probability above or below the reported value.

This stock assessment represents an update, following the full assessment conducted in 2022 (IPHC-2023-SA01). There are no structural changes to the assessment methods for 2023. Supporting analyses were reviewed by the IPHC's Scientific Review Board (SRB) in June (SRB022; IPHC-2023-SRB022-08, IPHC-2023-SRB022-R) and September 2023 (SRB023; IPHC-2023-SRB023-06, IPHC-2023-SRB023-R). The most important change in the 2022 full assessment was the estimation of natural mortality (M) in the short AAF model. Further investigation during 2023 supported the continued estimation of natural mortality in this model, and suggested that the estimated value is robust to the subtraction of recent data (retrospective testing) and the new information available for 2023.

COMPARISON WITH PREVIOUS ASSESSMENTS

As in recent analyses, the transition from the 2022 stock assessment to the final 2023 models was performed in a stepwise manner, adding data incrementally to identify which new information had the largest effect on the results. This 'bridging' analysis included the update to the stock synthesis software from version 3.30.19 to version 3.30.21 (Methot et al. 2023); however, there were no changes to the features used for this assessment nor any changes to the results as a function of the software update. The 2022 directed commercial fishery sex-ratio-at-age information was available prior to all other data sources and was therefore included as a separate step in the bridging analysis. The second step included updating the 2022 data where needed and adding the standard data sources for 2023, including FISS and commercial fishery indices, biological sampling and mortality estimates from all sectors. All four of the models showed only minor differences in the early portions of the time-series' (Figures 3-6). The 2023 data caused all of the models to estimate a lower spawning biomass for the most recent few years (2021+), and to slightly reduce the estimate of the 2012 year-class strength compared to the 2022 stock assessment. Further investigation revealed that the most important data source in this reduction was the commercial fishery CPUE index (see sensitivity analysis below).

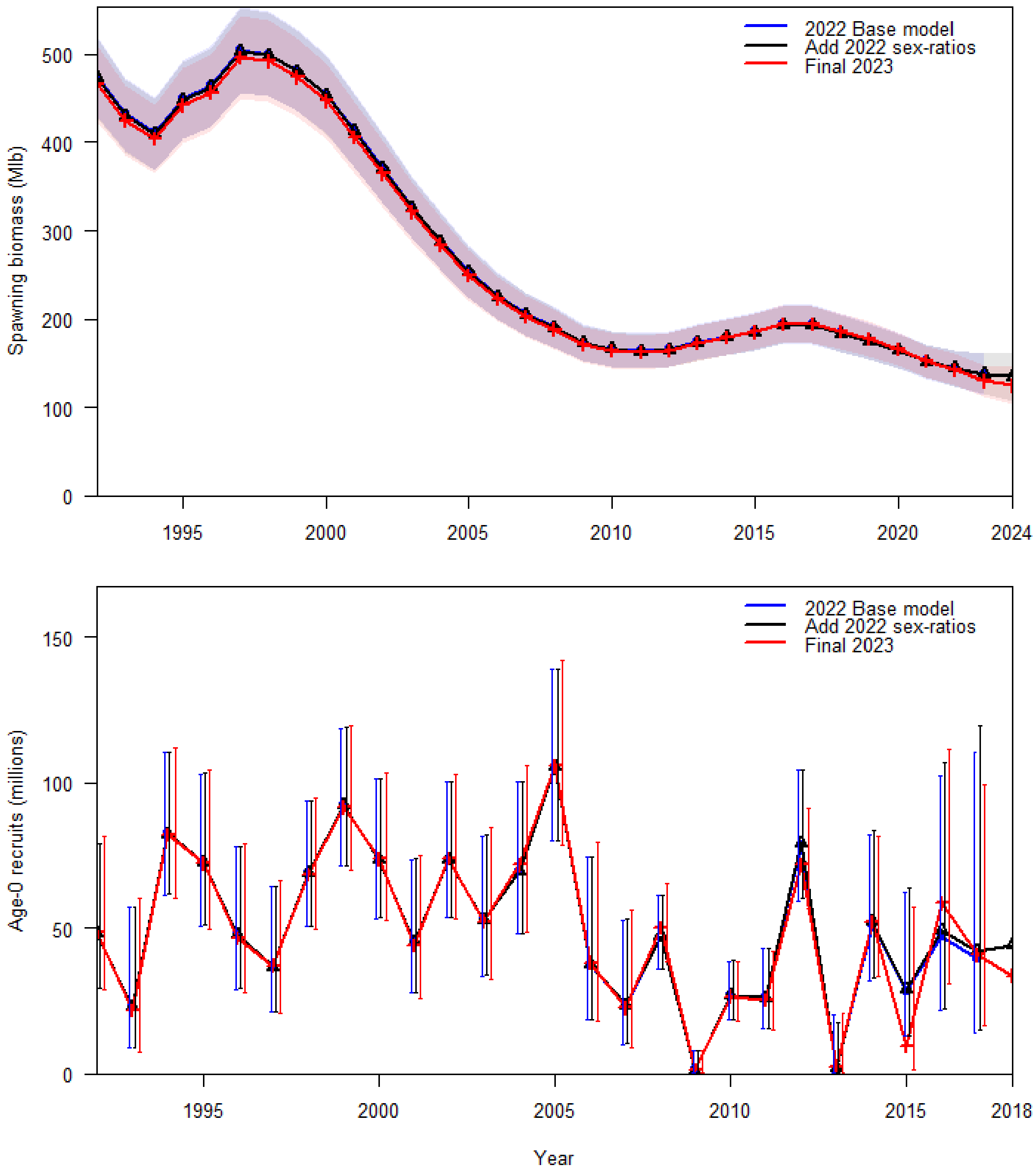

FIGURE 3. Bridging analysis showing the change from the 2022 to final 2023 stock assessment model estimates of spawning biomass (upper panel) and recruitment (lower panel) for the short coastwide model.

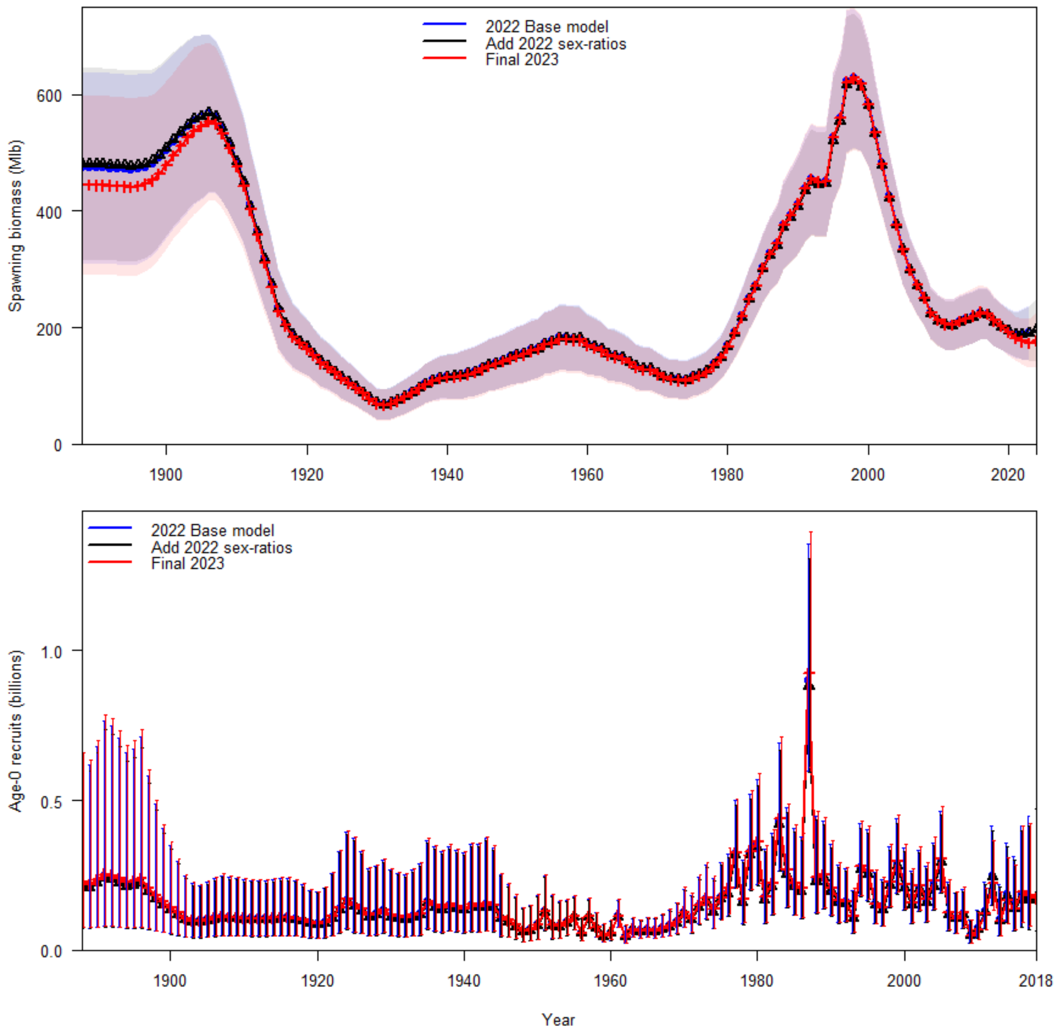

FIGURE 4. Bridging analysis showing the change from the 2022 to final 2023 stock assessment model estimates of spawning biomass (upper panel) and recruitment (lower panel) for the long coastwide model.

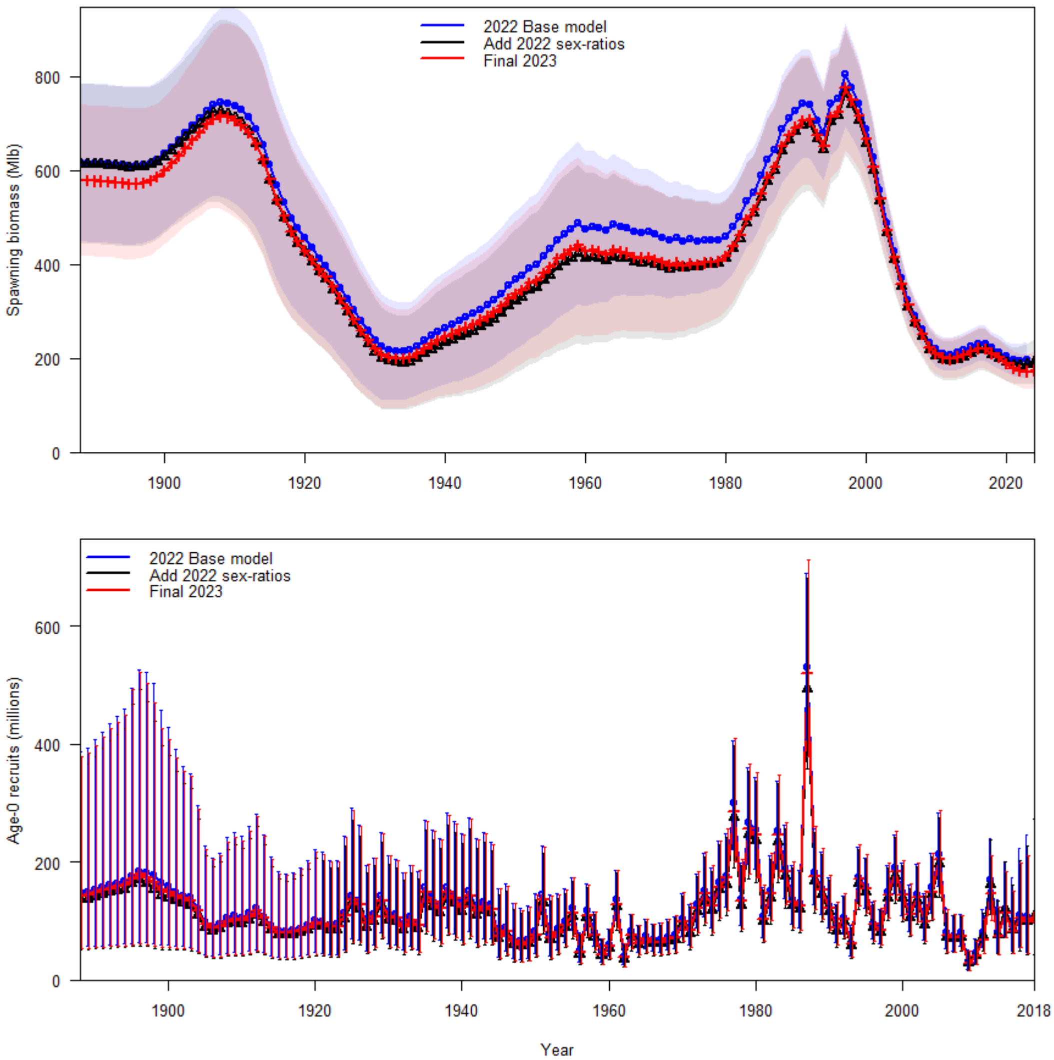

FIGURE 5. Bridging analysis showing the change from the 2022 to final 2023 stock assessment model estimates of spawning biomass (upper panel) and recruitment (lower panel) for the long AAF model.

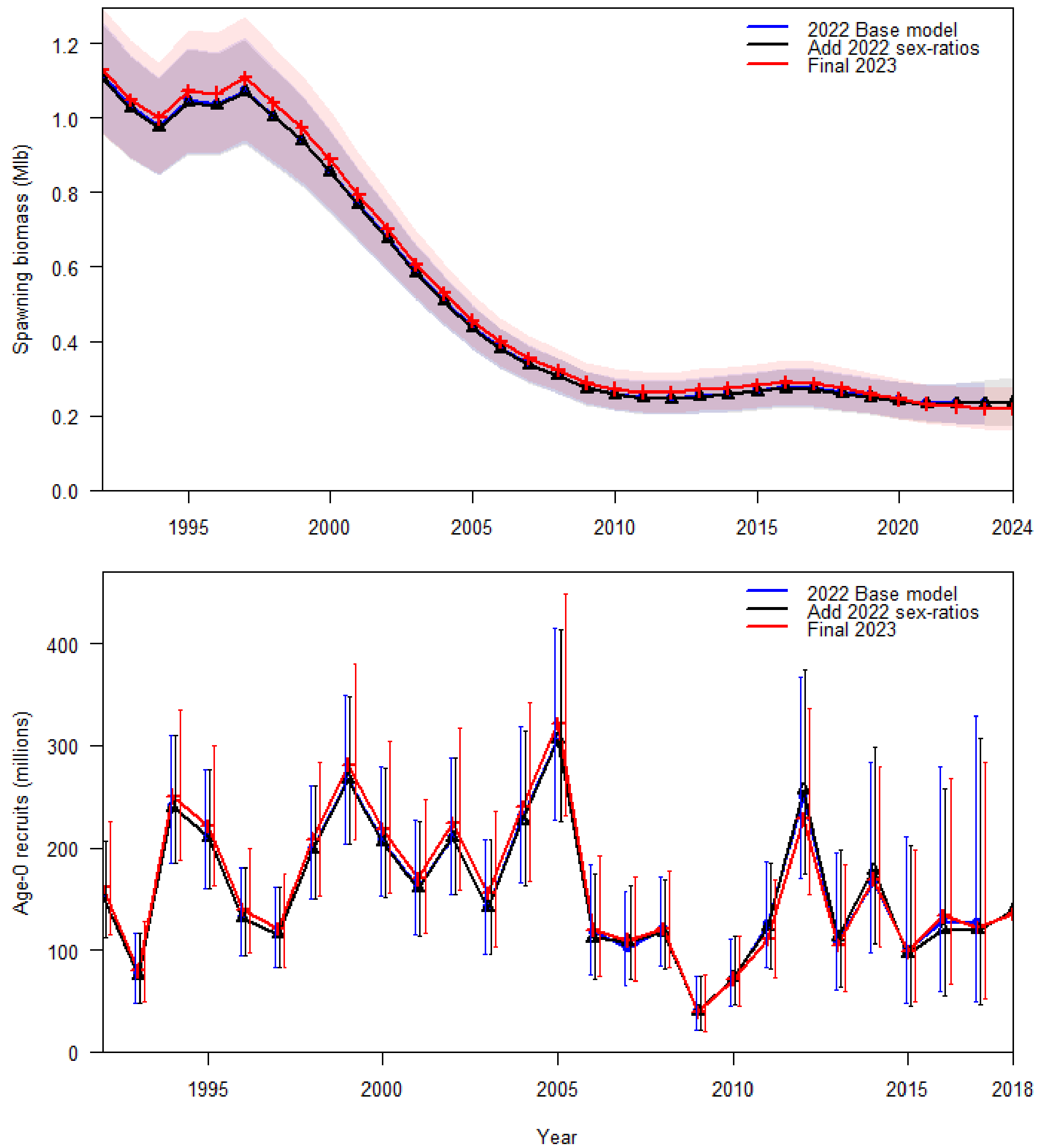

FIGURE 6. Bridging analysis showing the change from the 2022 to final 2023 stock assessment model estimates of spawning biomass (upper panel) and recruitment (lower panel) for the short AAF model.

Estimates for female Pacific halibut natural mortality from the three models where this parameter is estimated span values of 0.183 (AAF long), 0.216 (AAF short) and 0.217 (coastwide long); the coastwide short model retains the fixed value of 0.15. Comparison of this year's ensemble results with previous stock assessments indicates that the estimates of spawning biomass from the 2023 ensemble remain very consistent with those from the 2012-2019 assessments, but slightly below the terminal estimates from the 2020-2022 stock assessments. However, each of the previous terminal assessment values lie inside the predicted 50% interval of the current ensemble (Figure 7). The uncertainty is much greater prior to approximately 2005 reflecting the differences among the four individual models, particularly the beginning of the time-series' in the two short models. The estimated fishing intensity for the 2022 and 2023 stock assessments is generally lower than for older assessments due to the change in estimating female natural mortality in 2022. However, the 2023 stock assessment estimates a level of fishing intensity quite close to 5 out of 9 of these recent assessments and only slightly higher than the projection from the 2022 stock assessment (Figure 8).

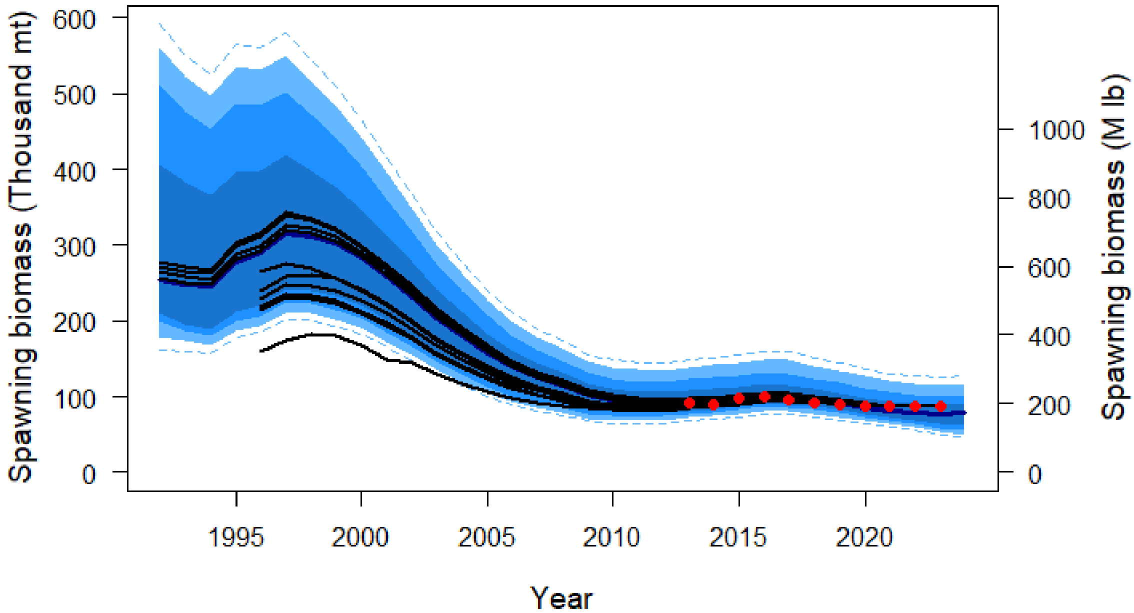

FIGURE 7. Retrospective comparison of female spawning biomass among recent IPHC stock assessments. Black lines indicate estimates from assessments conducted in 2012-2022 with the terminal estimate shown as a red point. The shaded distribution denotes the 2023 ensemble: the dark blue line indicates the 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.

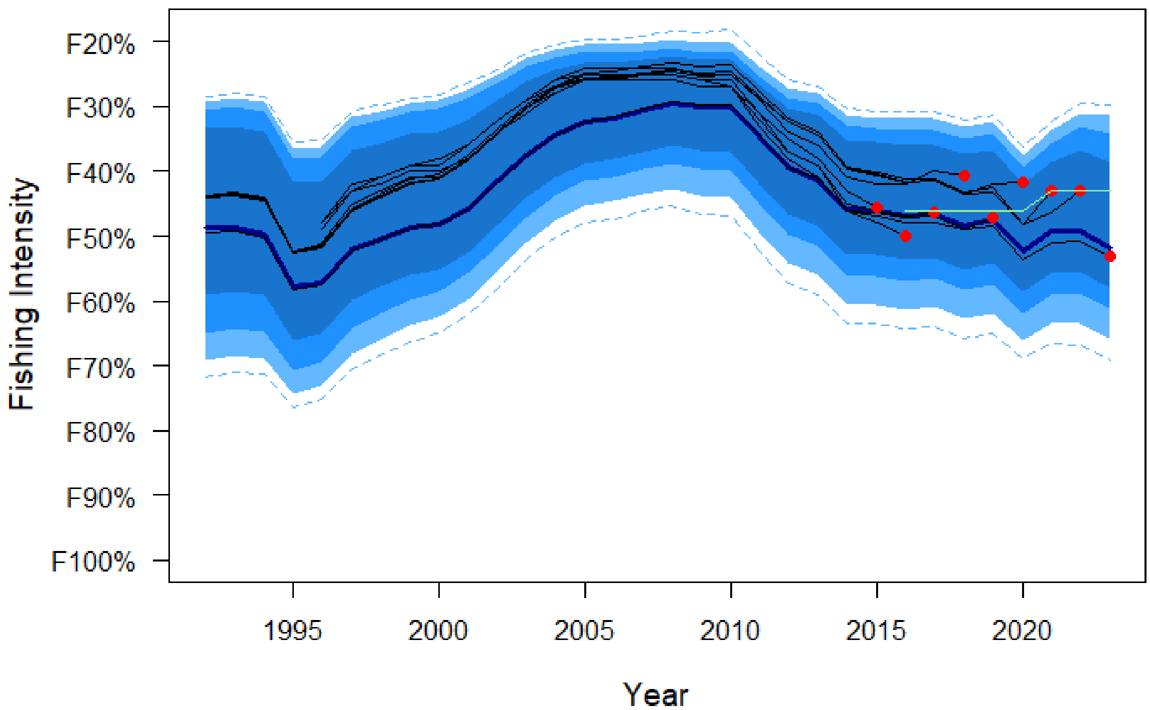

FIGURE 8. Retrospective comparison of fishing intensity (measured as $F_{xx\%}$, where xx% indicates the Spawning Potential Ratio (SPR) or the reduction in the lifetime reproductive output due to fishing) among recent IPHC stock assessments. Thin black lines indicate estimates of fishing intensity from assessments conducted in 2014-2022 with the projection for the mortality limit adopted based on that assessment shown as a red point. The shaded distribution denotes the 2023 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. The green line indicates the reference level of fishing intensity used by the Commission in each year it has been specified ($F_{46\%}$ during 2016-2020 and $F_{43\%}$ during 2021-2023).

BIOMASS, RECRUITMENT, AND REFERENCE POINT RESULTS

Ensemble

The results of the 2022 stock assessment indicate that the Pacific halibut stock declined continuously from the late 1990s to around 2012 (Figure 7, Table 1). That trend is estimated to have been largely a result of decreasing size-at-age, as well as lower recruitment than observed during the 1980s. The spawning biomass increased gradually to 2016, and then decreased to an estimated 171 million pounds (~77,500 t) at the beginning of 2023. At the beginning of 2024 the spawning biomass is estimated to have increased slightly (largely due to the rapidly maturing 2012 year-class) to 174 million pounds (78,900 t), with an approximate 95% credible interval ranging from 111 to 258 million pounds (~50,400-116,900 t; Figure 9). The differences among the individual models contributing to the ensemble are most pronounced prior to the early 2000s (Figure 10); however, current stock size estimates (at the beginning of 2023) also differ substantially among the four models (Figure 11). The differences in both scale and recent trend reflect the structural assumptions, e.g., higher natural mortality estimated in three models and dome-shaped selectivity for Biological Regions 2 and 3 in the AAF models.

TABLE 1. 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
1992	560	392-1237	49%	29-69%	164.6	48.5	103.0	161.2	1,660	1,141	2,194	3,300
1993	547	382-1153	49%	29-68%	111.6	21.7	61.7	79.5	1,555	1,087	2,029	3,032
1994	540	371-1098	50%	29-69%	281.9	82.1	170.6	250.9	1,484	1,020	1,915	2,815
1995	613	411-1181	58%	36-74%	265.5	72.3	155.7	221.4	2,070	1,352	2,381	3,487
1996	639	426-1172	57%	36-73%	156.4	46.8	94.3	139.6	2,036	1,344	2,362	3,391
1997	696	465-1214	52%	32-68%	141.6	37.2	85.0	120.6	2,096	1,406	2,425	3,425
1998	689	462-1140	50%	31-66%	227.4	68.5	145.0	208.6	1,997	1,361	2,294	3,200
1999	668	445-1068	49%	30-64%	295.2	91.7	185.0	281.6	1,840	1,266	2,110	2,908
2000	626	419-974	48%	29-62%	219.6	73.9	144.2	218.1	1,670	1,169	1,927	2,631
2001	572	380-871	46%	27-60%	158.8	44.1	111.8	169.8	1,473	1,034	1,710	2,299
2002	511	340-767	42%	25-55%	214.8	74.2	140.5	224.3	1,410	985	1,613	2,152
2003	449	299-665	38%	23-51%	169.8	52.4	99.8	155.8	1,347	928	1,512	1,999
2004	396	263-581	35%	21-48%	229.9	71.8	149.4	239.6	1,228	851	1,378	1,813
2005	347	232-502	32%	20-45%	306.8	105.9	205.8	321.7	1,106	762	1,242	1,625
2006	307	206-440	32%	21-45%	126.3	38.0	75.4	119.1	1,049	718	1,171	1,530
2007	276	187-394	31%	20-43%	106.8	22.6	72.9	109.7	1,045	710	1,149	1,515
2008	252	174-360	30%	20-43%	126.4	50.3	75.0	120.9	994	685	1,100	1,458
2009	224	157-323	30%	20-44%	50.3	1.4	28.9	39.4	899	619	1,011	1,346
2010	211	151-307	30%	20-44%	69.5	26.6	42.0	71.8	861	604	969	1,305
2011	203	149-299	35%	24-49%	119.9	25.3	68.2	110.7	815	577	912	1,235
2012	201	151-297	39%	27-54%	222.7	72.0	145.8	227.9	814	581	905	1,238
2013	207	158-306	41%	28-56%	96.3	2.4	74.0	104.4	866	631	954	1,313
2014	211	164-312	46%	31-60%	166.7	52.3	114.5	169.4	822	612	909	1,248
2015	217	170-320	46%	32-61%	139.3	9.5	83.1	98.5	774	580	869	1,184
2016	223	178-329	47%	32-61%	196.4	58.6	105.3	133.4	753	588	842	1,147
2017	222	177-326	47%	32-61%	184.2	40.9	98.2	122.5	687	535	781	1,052
2018	211	170-311	48%	33-63%	173.5	33.7	106.1	135.3	633	507	724	977
2019	202	161-296	47%	32-62%	NA	NA	NA	NA	625	483	699	950
2020	190	151-281	52%	38-66%	NA	NA	NA	NA	693	522	753	1,034
2021	180	139-266	49%	34-64%	NA	NA	NA	NA	666	462	738	1,000
2022	175	130-260	49%	31-64%	NA	NA	NA	NA	691	475	761	1,026
2023	171	118-255	52%	31-66%	NA	NA	NA	NA	693	419	748	975
2024	174	111-258	NA	NA	NA	NA	NA	NA	744	452	767	970

Differences are also apparent in the absolute scale of recent recruitment estimates; however, relative recruitments from all four models show larger year-classes in 1999 and 2005 than in all subsequent years, with 2012 being estimated to be lower than the magnitude of the 2005 year-class (Figure 12, Table 1). 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 13). Cohorts from 2006 through 2011 are estimated to be much smaller than those from 1999-2005 which has resulted in declines in both the stock and fishery yield as these low recruitments became increasingly important to the age range over which much of the harvest and spawning takes place. Based on the most recent trend and age data, this assessment estimated the 2012 cohort to be critically important to the projected spawning biomass over the next 2-4 years. Forty-two percent (42%) of this cohort is estimated to be mature in 2023 and increasing to 80% by 2026, assuming the historical average maturity schedule currently used in the assessment. Current estimates of the 2014 cohort indicate a high probability that it is below the 2012 cohort and therefore unlikely to appreciably change the short-term stock projections or fishery yields. All models are estimating a slightly increasing or stable 8+ biomass from a low in 2018 or 2019 and the ensemble shows a similar pattern in the spawning biomass through the beginning of 2024 (Table 1). Recruitment estimates after 2015 remain highly uncertain, and those after 2017 are poorly informed by any direct information from the fishery and survey data.

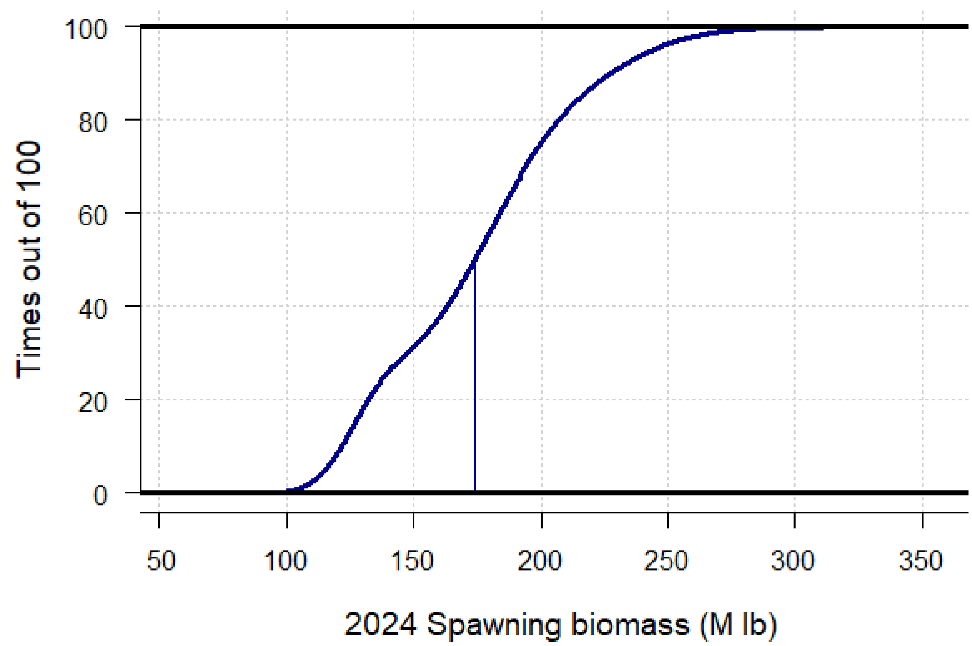

FIGURE 9. Cumulative distribution of the estimated spawning biomass at the beginning of 2024. Curve represents the estimated probability that the biomass is less than or equal to the value on the x-axis; vertical line represents the median (174 million pounds; ~79,900 t).

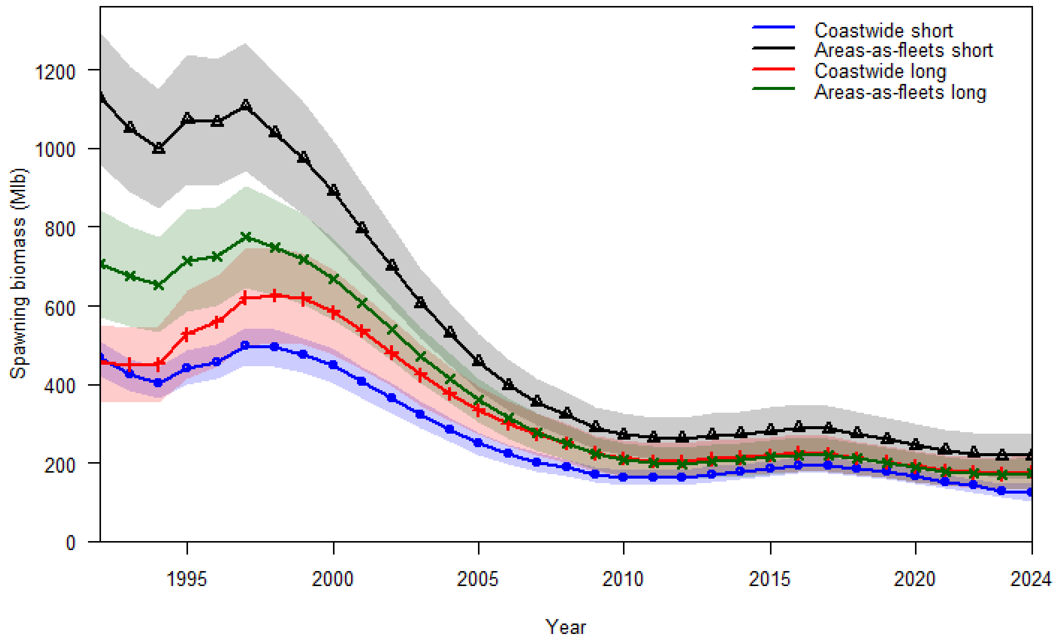

FIGURE 10. Estimated spawning biomass trends (1992-2024) based on the four individual models included in the 2023 stock assessment ensemble. Series indicate the maximum likelihood estimates; shaded intervals indicate approximate 95% credible intervals.

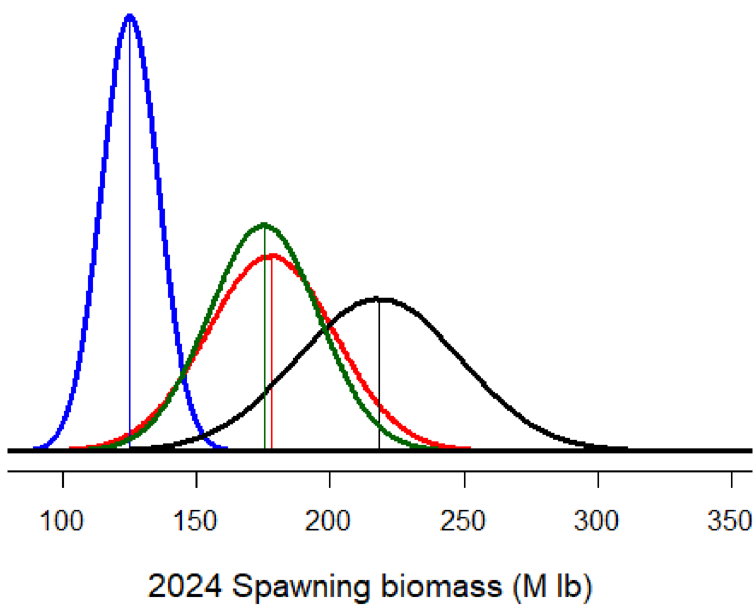

FIGURE 11. Distribution of individual model estimates for the 2024 spawning biomass. Vertical lines indicate the median values.

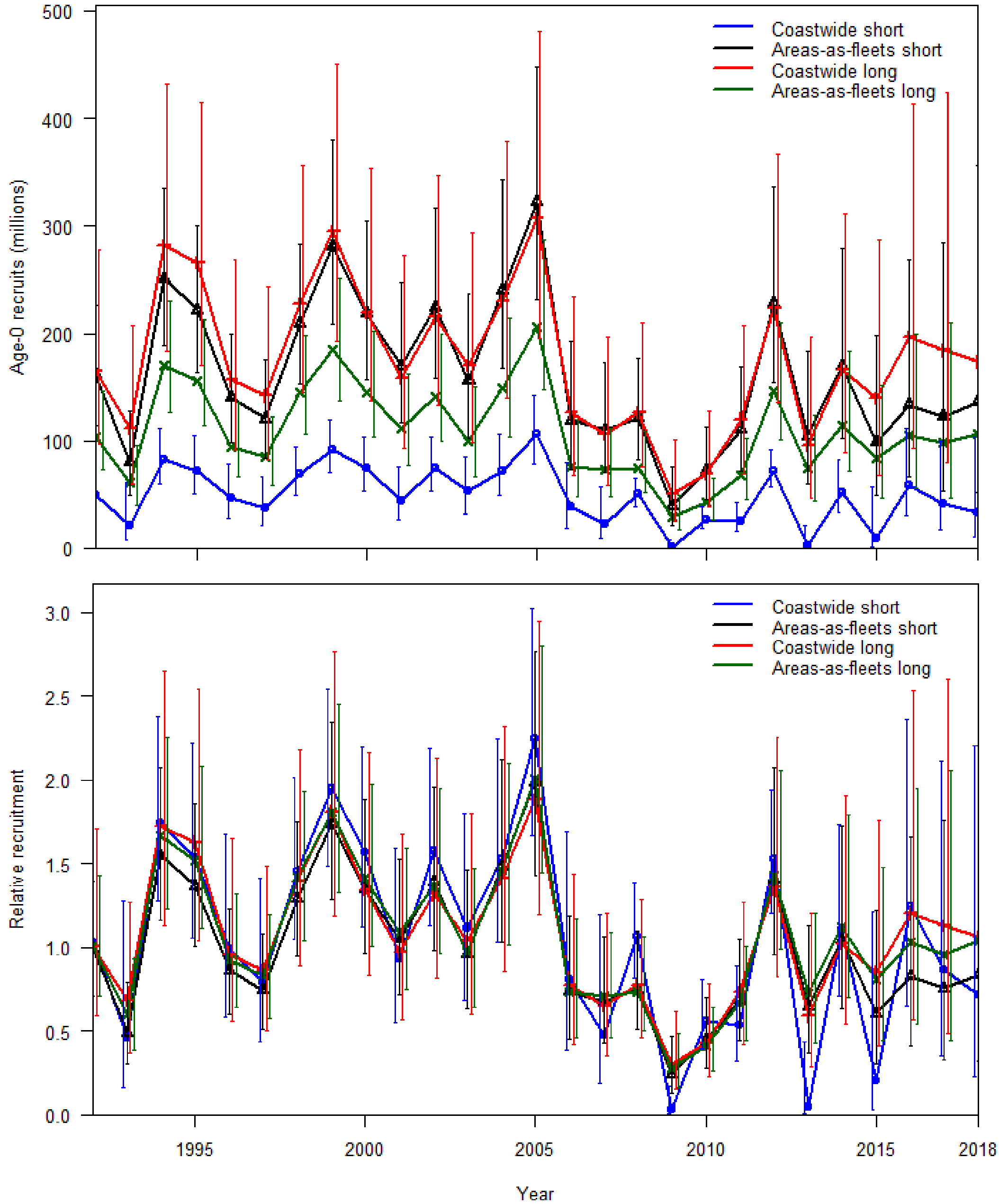

FIGURE 12. Estimated trends in age-0 recruitment (upper panel) and relative recruitment (standardized to the mean for each model over this time-period; lower panel) 1992-2018, based on the four individual models included in the 2023 stock assessment ensemble. Series indicate the maximum likelihood estimates; vertical lines indicate approximate 95% credible intervals.

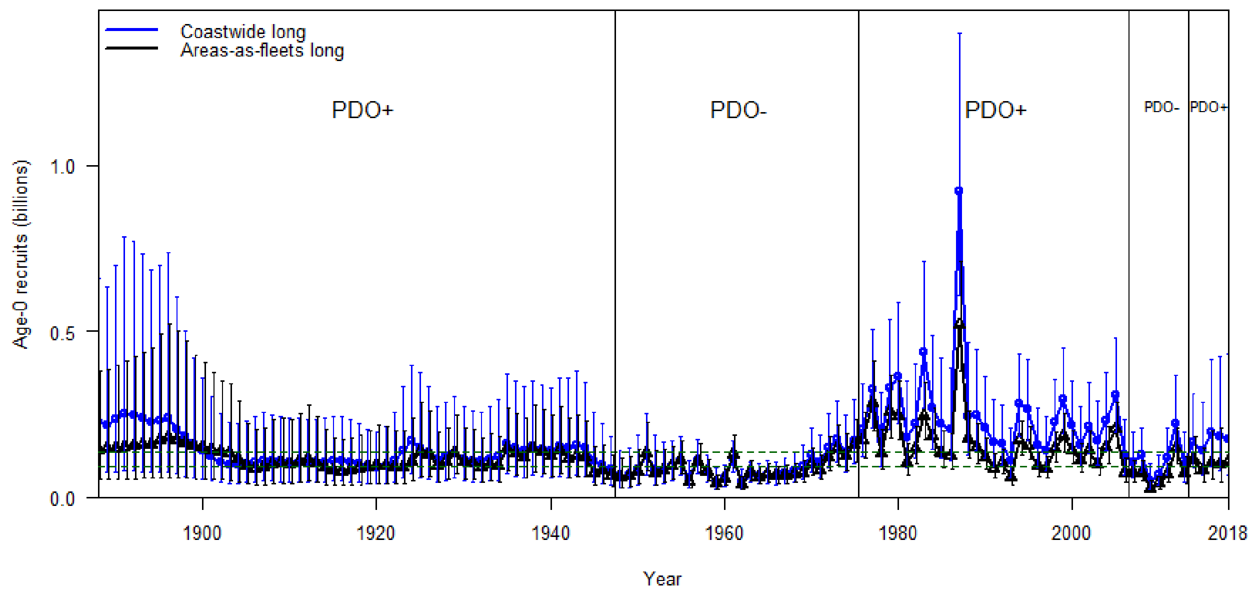

FIGURE 13. Trend in historical recruitment strengths (by birth year) estimated by the two long time-series models, including the effects of the Pacific Decadal Oscillation (PDO) regimes.

Ecosystem conditions

Average Pacific halibut recruitment is estimated to be higher (53 and 50% 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 through 2023 showing negative average conditions (data were only available through October for 2023). Although strongly correlated with historical recruitments, it is unclear whether the effects of climate change and other recent anomalous conditions in both the Bering Sea and Gulf of Alaska are comparable to those observed in previous decades.

Reference points

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. 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 that are influencing the current stock only, the 'dynamic' calculation measures the effect of fishing on the spawning biomass. The relative spawning biomass decreased continuously over the period 1992-2012 to near 30% (Figure 14). Since 2016, the relative spawning biomass has increased slightly to 42% at the beginning of 2023 (credible interval: 20-56%). This result indicates that recruitment and size-at-age have generally been more important to the trend in spawning biomass than fishing, particularly over the last few years. That the spawning biomass has been decreasing in recent years and the relative spawning biomass has been increasing is not inconsistent: the biomass projected to occur in the absence of fishing (the denominator of the relative biomass calculation) has also been decreasing, and at a higher rate than the actual estimated spawning biomass (Figure 15). The probability that the stock is below the $SB_{30\%}$ level is estimated to be 26% at the beginning of 2023, with a 1% chance that the stock is below $SB_{20\%}$ (Figure 16).

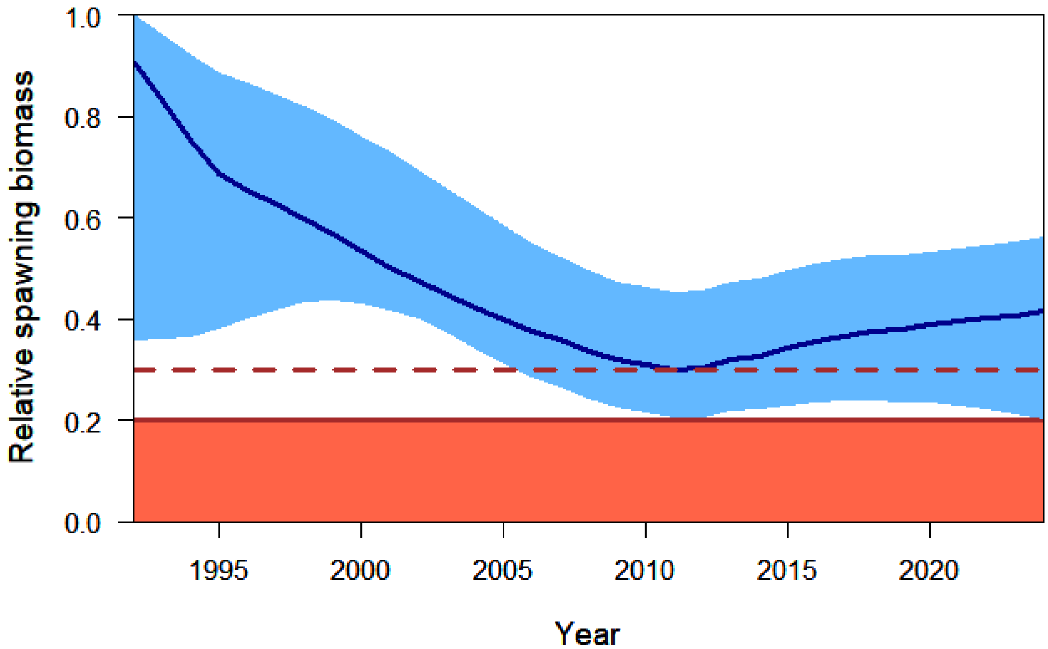

FIGURE 14. Estimated time-series of relative spawning biomass (compared to the unfished condition in each year) based on the median (dark blue line) and approximate 95% credibility interval (blue shaded area). IPHC management procedure reference points ($SB_{30\%}$ and $SB_{20\%}$) are shown as dashed and solid lines respectively, with the region of biological concern ($<SB_{20\%}$) shaded in red.

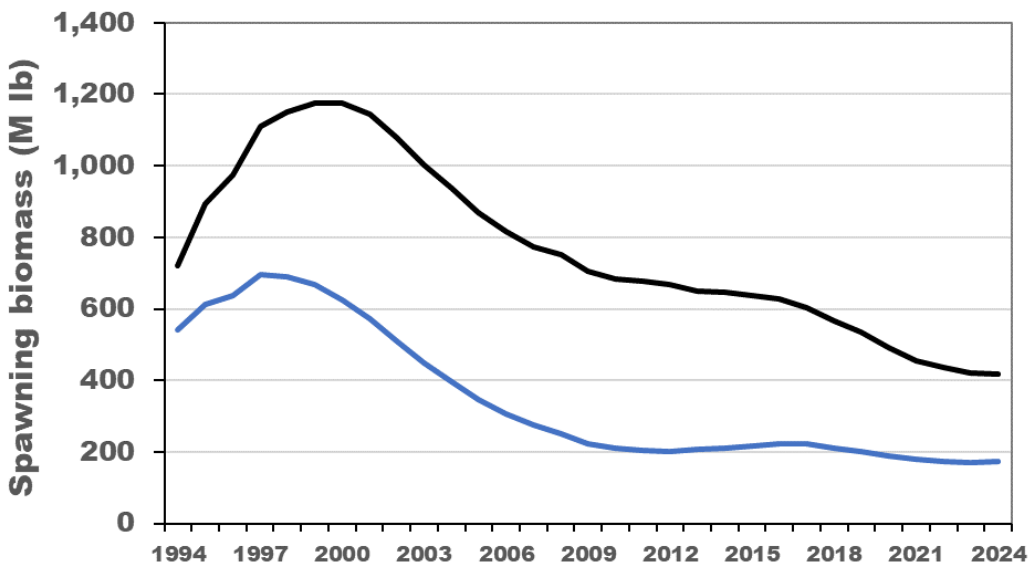

FIGURE 15. Estimated time-series' of spawning biomass (blue line) and spawning biomass in the absence of fishing (black line).

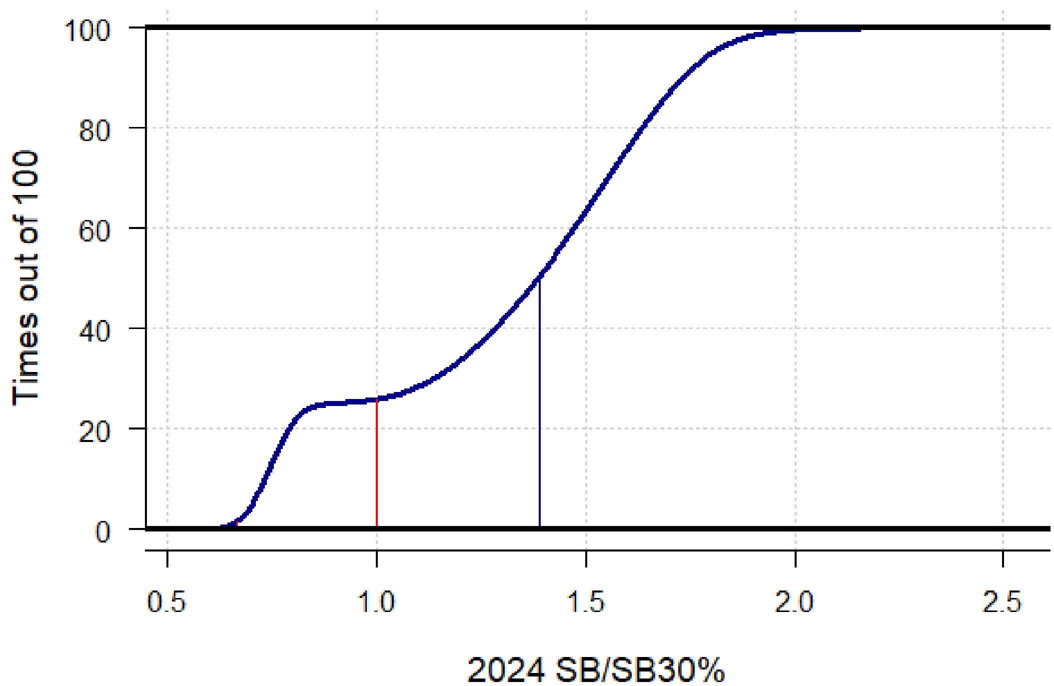

FIGURE 16. Cumulative distribution of ensemble 2024 spawning biomass estimates relative to the $SB_{30\%}$ reference point. Curve represents the estimated probability that the biomass is less than or equal to the value on the x-axis. Vertical lines denote the values corresponding to the fishing intensity threshold in the IPHC's harvest policy (red; $SB_{30\%}$), and the median (blue; $SB_{42\%}$).

The IPHC's current interim management procedure specifies a reference level of fishing intensity of $F_{43\%}$, based on the Spawning Potential Ratio (SPR). This reference 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. For the most recent three years fishing intensity is estimated to have been below reference levels. Prior to 2020, estimates of terminal year fishing intensity in each stock assessment were generally similar to those from the 2023 assessment (Figure 8). Based on the 2023 assessment, the 2023 fishing intensity is estimated to correspond to an $F_{52\%}$ (credible interval: 31-66%), slightly higher than projected in the 2022 assessment, similar to 2020, and lower than all other years since the late 1990s (Table 1; Figures 17 and 18). 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 has increased slowly since then (Figure 18).

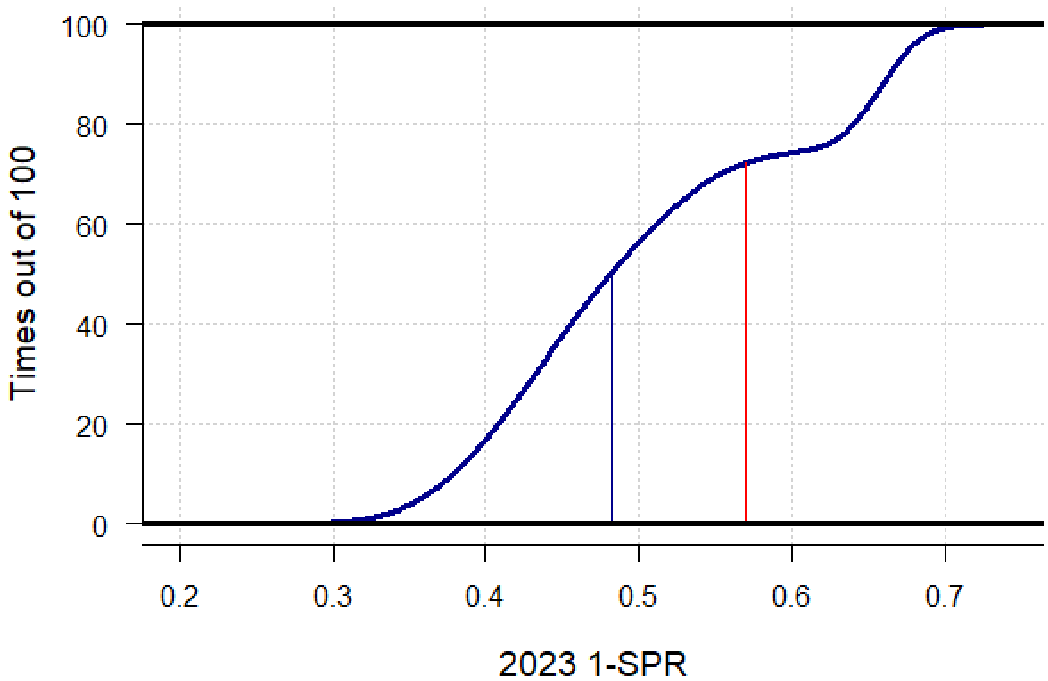

FIGURE 17. Cumulative distribution of the estimated fishing intensity (based on the Spawning Potential Ratio) estimated to have occurred in 2023. Curve represents the estimated probability that the fishing intensity is less than or equal to the value on the x-axis. Vertical lines indicate the reference ($F_{43\%}$; red) and the median value ($F_{51\%}$; blue).

Long time-series models

The two long time-series models provided different perceptions of current vs. historical stock sizes, particularly for the lowest points in the series occurring in the 1930s and 1970s (Figure 19). The AAF model estimates that recent stock sizes are below those estimated for the 1970s, and the coastwide model above. 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 four of the models represent only simple approximations. Recent differences are small, and likely attributable to the separation of signals from each Biological Region (particularly Region 2, with the longest time-series of data), and allowance for different properties in each region's fishery and survey in the AAF models. Historical differences appear to be due to the differing implicit 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).

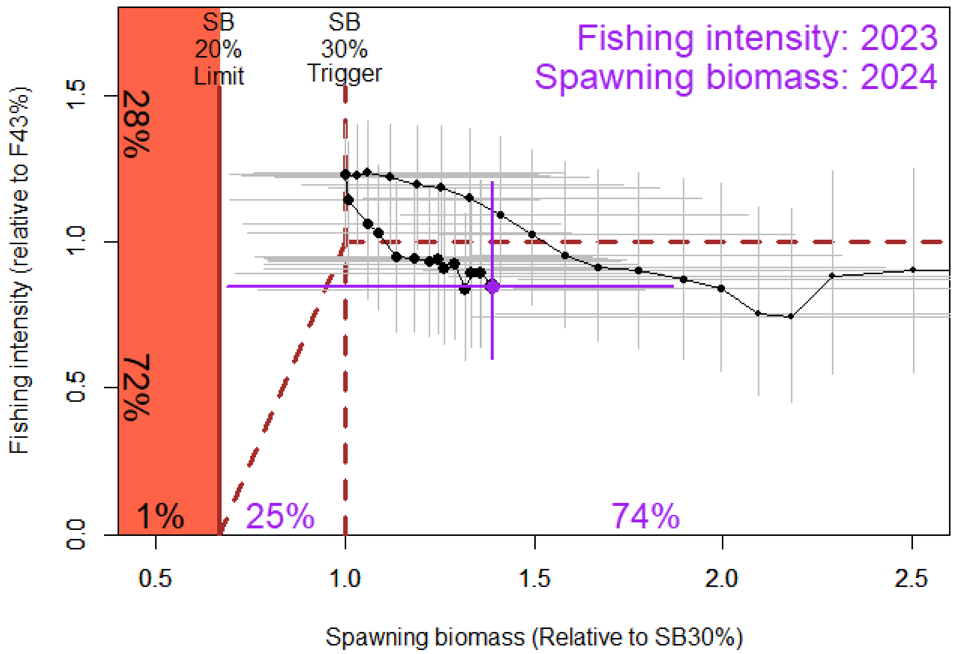

FIGURE 18. Phase plot showing the time-series of estimated spawning biomass (1993-2024) and fishing intensity (1992-2023) relative to current reference points. Dashed lines indicate the $F_{43\%}$ (horizontal) reference fishing intensity and linear reduction below the $SB_{30\%}$ (vertical) trigger, the red area indicates levels below the $SB_{20\%}$ limit. Each year is denoted by a solid point (credible intervals by horizontal and vertical whiskers), with the relative fishing intensity in 2023 and spawning biomass at the beginning of 2024 shown as the largest point (purple). Percentages along the y-axis indicate the probability of being above and below $F_{43\%}$ in 2023; 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 2024.

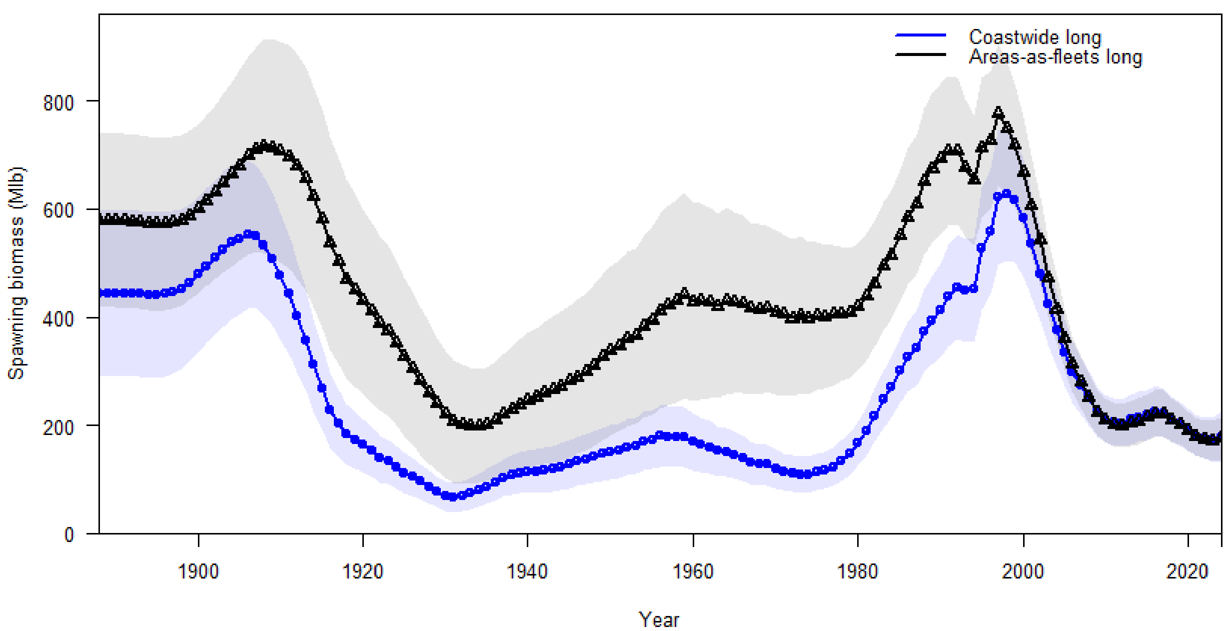

FIGURE 19. Spawning biomass estimates from the two long time-series models. Shaded region indicates the approximate 95% within-model credible interval. The black (upper) series is the Areas-As-Fleets model and the blue (lower) series is the coastwide model.

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

The 2023 assessment includes six years (2017-22) of sex-ratio information from the directed commercial fishery landings. However, uncertainty in historical ratios, and the degree of variability likely present in those historical ratios remains unknown. Additional years of data are likely to further inform selectivity parameters and cumulatively reduce uncertainty in stock size moving into the future. The treatment of spatial dynamics (and implicitly 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. Further, movement rates for adult and younger Pacific halibut (roughly ages 2-6, which were not well-represented in the PIT-tagging study), particularly to and from Biological 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. 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. Ongoing research to better understand the stock structure within the Convention Area as well as connectivity to Western North Pacific waters is ongoing. These investigations are particularly important for understanding the dynamics in IPHC Regulatory Area 4B, which is potentially the most demographically isolated of the eight IPHC Regulatory Areas.

Additional important contributors to assessment uncertainty (and potential bias) include factors influencing recruitment, size-at-age, and some estimated components of fishery mortality. 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 (8+ years) and survey data (6+ years). Reduced size-at-age relative to levels observed in the 1970s has been the most important driver of recent decade's stock productivity, but its cause also remains unknown. Like most stock assessments, fishing 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 mortality in either directed or non-directed fisheries (e.g. whale/marine mammal depredation) could create bias in this assessment. For 2023 an extensive evaluation of marine mammal depredation was undertaken. Adding the best available estimate of this source of unobserved mortality resulted in slightly higher spawning biomass estimates from the stock assessment, but when projections of depredation mortality were removed from projected mortality limits the net change to fishery yield from the current assessment was negligible: the two factors largely canceled each other out. A summary of the results of these analyses is available in the documents reviewed by the IPHC's Scientific Review Board during 2023 (IPHC-2023-SRB022-08; IPHC-2023-SRB023-06).

Maturation schedules are currently under renewed investigation by the IPHC. 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 the spatial and temporal variability inherent in these biological processes.

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, as in 2022, the four models use both fixed (0.15/year for female Pacific halibut) and estimated values. Estimates are highly correlated with the relative commercial fishery selectivity of males and females, which is currently estimated based on only six years of available data. Although this uncertainty is directly incorporated into the ensemble results, uncertainty in female natural mortality in the coastwide short model is not and remains an avenue for future investigation.

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. 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, which can result in variable mortality limits from year to year. Potential solutions to reduce the inter-annual variability in mortality limits include management procedures that utilize multi-year management approaches, which are being tested with the MSE framework.

CONVERGENCE, SENSITIVITY AND RETROSPECTIVE ANALYSES

Basic convergence checks applied to all models included successful calculation of the Hessian matrix, checks for reasonable uncertainty in and correlations among estimated model parameters and tracking of results through sequential model or data changes to ensure plausible results. Final model runs were further evaluated via running models from a wide range starting values ('jittering', using at least 100 different starting points), and ensuring that no model discovered a better likelihood than was used to produce the final assessment results.

Following the bridging analysis of stepwise introduction of new data toward the final 2023 stock assessment an additional sensitivity analysis was conducted to isolate the data set that had the largest overall effect on the ensemble results. As noted above, the commercial fishery CPUE time series showed a strong drop in both 2022 and 2023 and was largely responsible for the lower spawning biomass estimates at the end of the time series (2020+). When the ensemble estimates were produced leaving out this single source of information, the results showed much closer agreement with recent stock assessments (Figure 20).

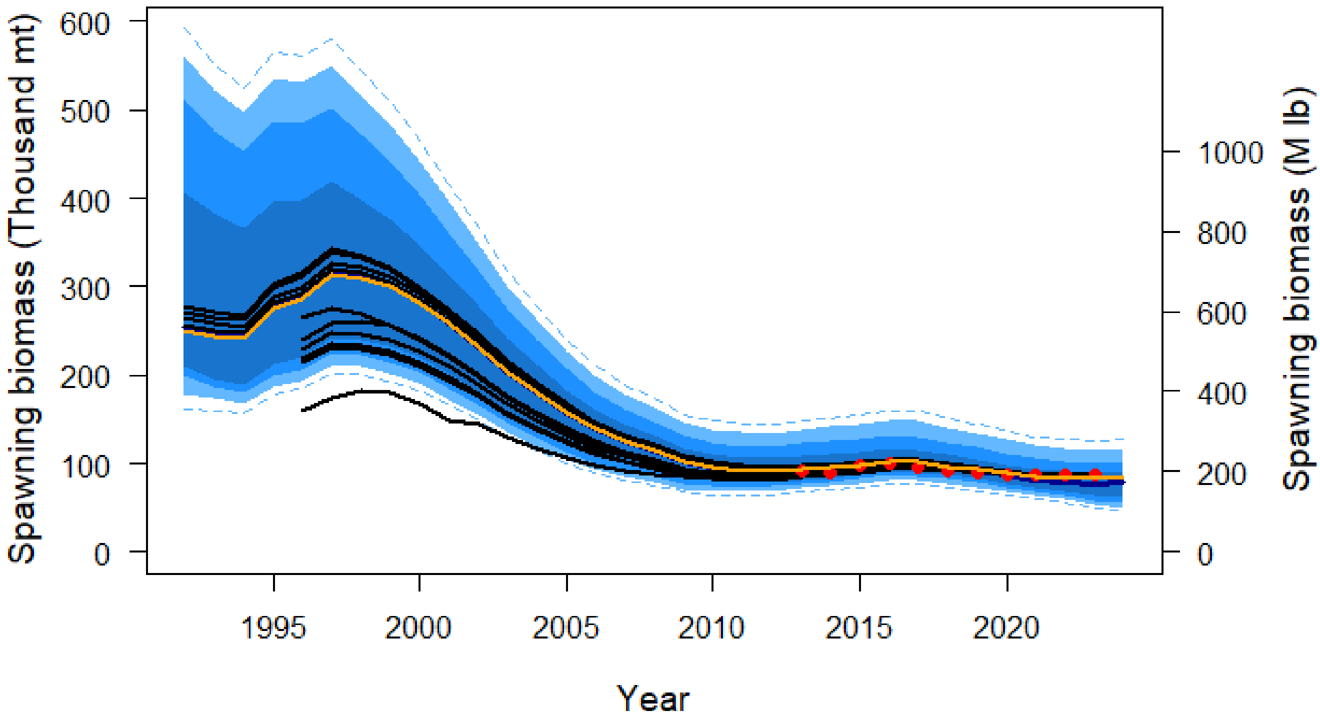

FIGURE 20. Sensitivity analysis to the removal of commercial fishery CPUE information from 2023 (yellow line) compared to the retrospective comparison of female spawning biomass among recent IPHC stock assessments. Black lines indicate estimates from assessments conducted in 2012-2022 with the terminal estimate shown as a red point. The shaded distribution denotes the 2023 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.

During the development of the 2022 full stock assessment a wide range of bridging and sensitivity analyses were conducted (IPHC-2022-SRB020-07). 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 have included: the sex ratio of the directed commercial fishery landings, the treatment of historical selectivity in the long time-series models, and natural mortality. Likelihood profiles were used to investigate the sources of information on natural mortality and the general level of agreement among data sets. In addition, the 2022 assessment included extensive evaluation of the treatment of the PDO as a covariate with average recruitment. Briefly, the way in which the PDO was linked to recruitment did not have a large effect of estimates of stock trend, nor was a method identified that better explained the historical variation. Research priorities closely linked with stock assessment uncertainties have been explored previously through specific sensitivity analyses conducted in recent assessments. In addition to those factors described above, these analyses have included the effects of unobserved whale depredation, and trends in spawning output (due to skip spawning or changes in maturity schedules) and the results have supported the prioritization of maturity, fecundity and skip spawning as current and near-term research foci.

To illustrate the effects of recent data, separate from all other model changes and data updates, retrospective analyses were performed for each of the individual models contributing to the assessment. This exercise consists of sequentially removing the terminal year's data and rerunning the assessment model. The current models rely on commercial sex-ratios-at-age which are only available from 2017-2022. Therefore, the retrospective for this year's assessment includes six 'peels', each cumulatively removing one year of data (2023, 2022-2023, 2021-2023, 2020-2023, 2019-2023, and 2018-2023). Estimates for relative male and female selectivity parameters become less certain with reduced data and required at least one year of data for reliable estimation and preferably more. As data accumulate since this change in model structure the retrospective analyses will be more informative of recent data effects rather than being affected by lack of information to inform selectivity differences.

The retrospective analysis revealed that spawning biomass time series for each of the four stock assessment models changed very little as the terminal year's data were removed; with the highest variance in the results observed for the AAF short and long models where the estimates of spawning biomass decreasing with the removal of 2-6 years of data and in the coastwide long model with spawning biomass increasing (Figures 21-24; upper panels). As noted above, these models were very sensitive to the estimated values for natural mortality, which were correlated with relative male and female selectivity in the directed commercial fishery; removing four and five recent years of data left a paucity of sex ratio information to estimate differences in male and female selectivity. This result highlights the ongoing need for additional observations of the sex-ratio of commercial fishery landings, although as more data are collected it may be possible to reduce the frequency at which sex ratio data are included. The second clear result from the retrospective analysis was the effect of 2018 to 2021 data on the magnitude of the estimated 2012 year-class. This cohort is informed by each year of additional data and the estimated magnitude increased strongly across the model runs (Figures 21-24; lower panels). The addition of the 2023 data resulted in only a small decrease in the estimate of the 2012 year-class.

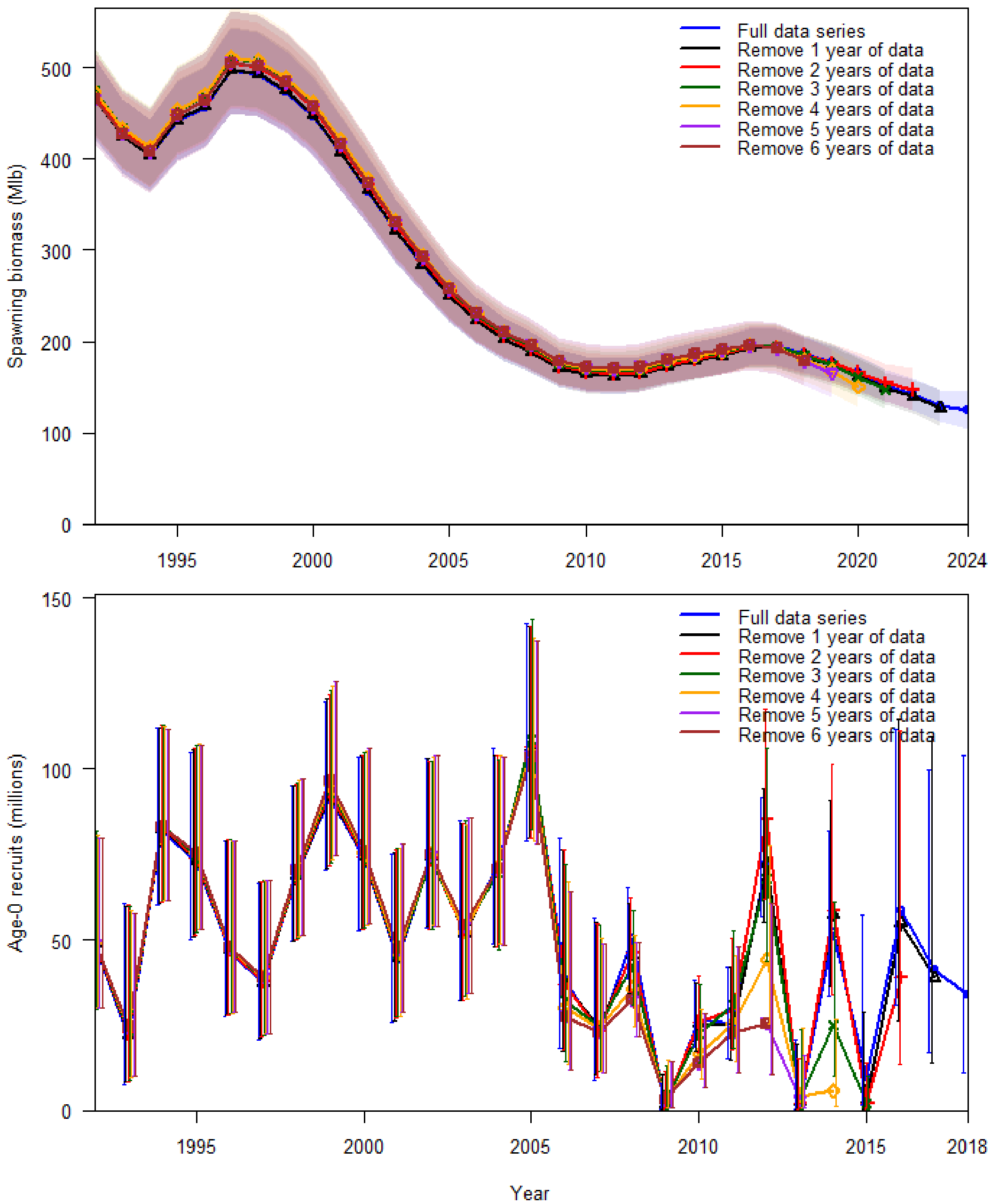

FIGURE 21. Spawning biomass (top panel) and recruitment (bottom panel) estimates from a retrospective analysis sequentially removing terminal years of data from the coastwide short model. Shaded regions and vertical whiskers indicate approximate 95% within-model credible intervals.

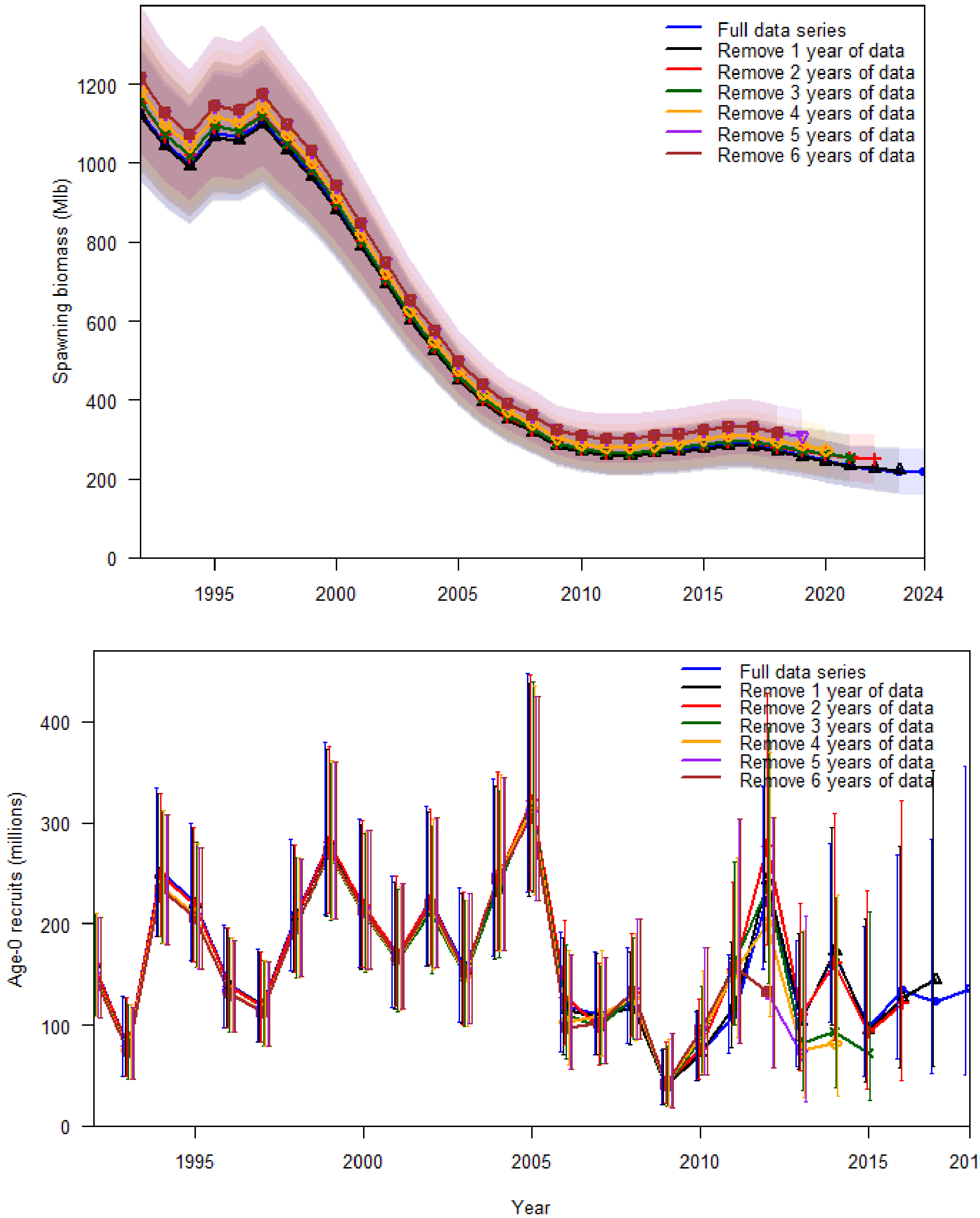

FIGURE 22. Spawning biomass (top panel) and recruitment (bottom panel) estimates from a retrospective analysis sequentially removing terminal years of data from the AAF short model. Shaded regions and vertical whiskers indicate approximate 95% within-model credible intervals.

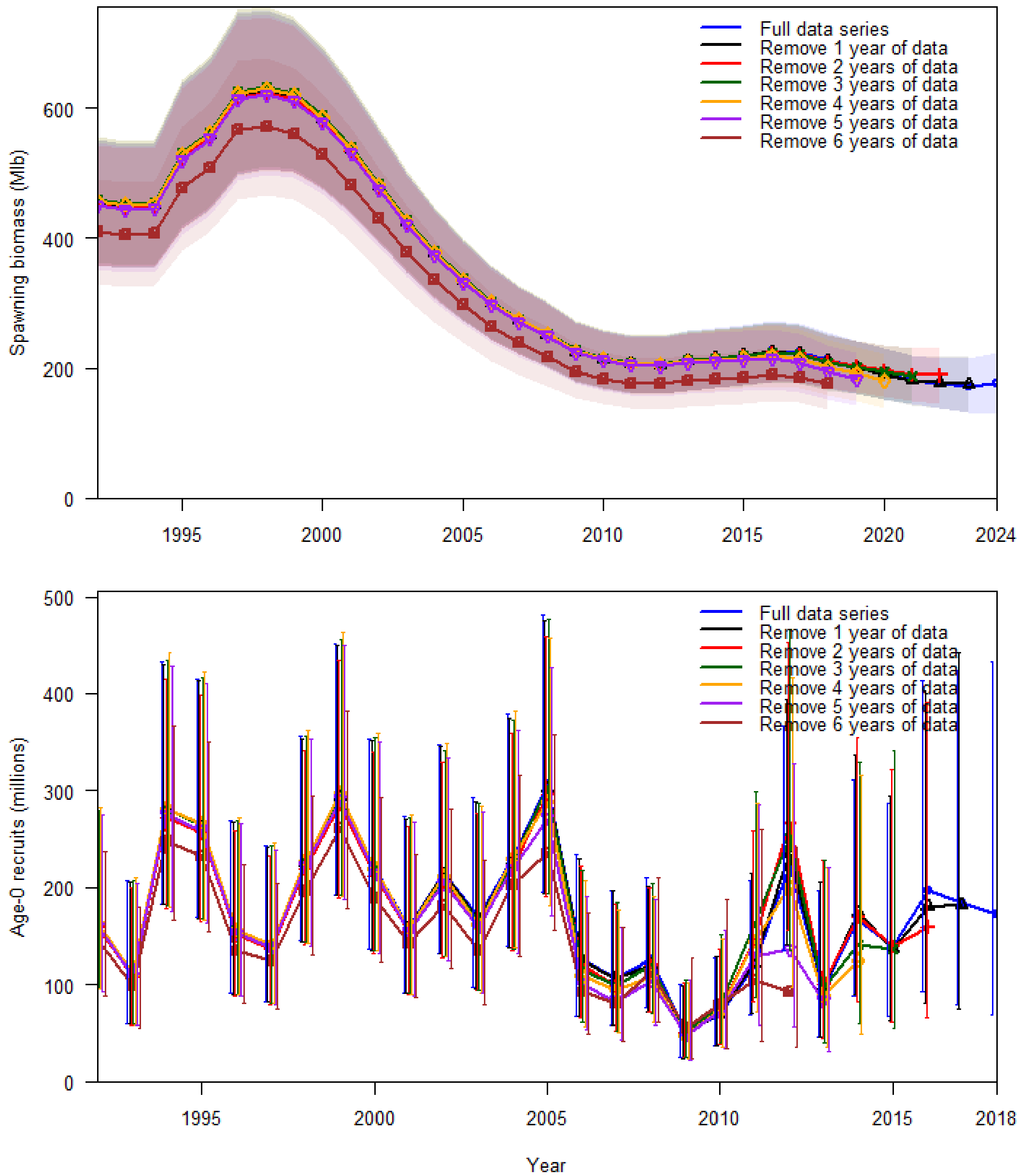

FIGURE 23. Recent spawning biomass (top panel) and recruitment (bottom panel) estimates from a retrospective analysis sequentially removing terminal years of data from the coastwide long model (time series has been truncated to allow for easier inspection of terminal values). Shaded regions and vertical whiskers indicate approximate 95% within-model credible intervals.

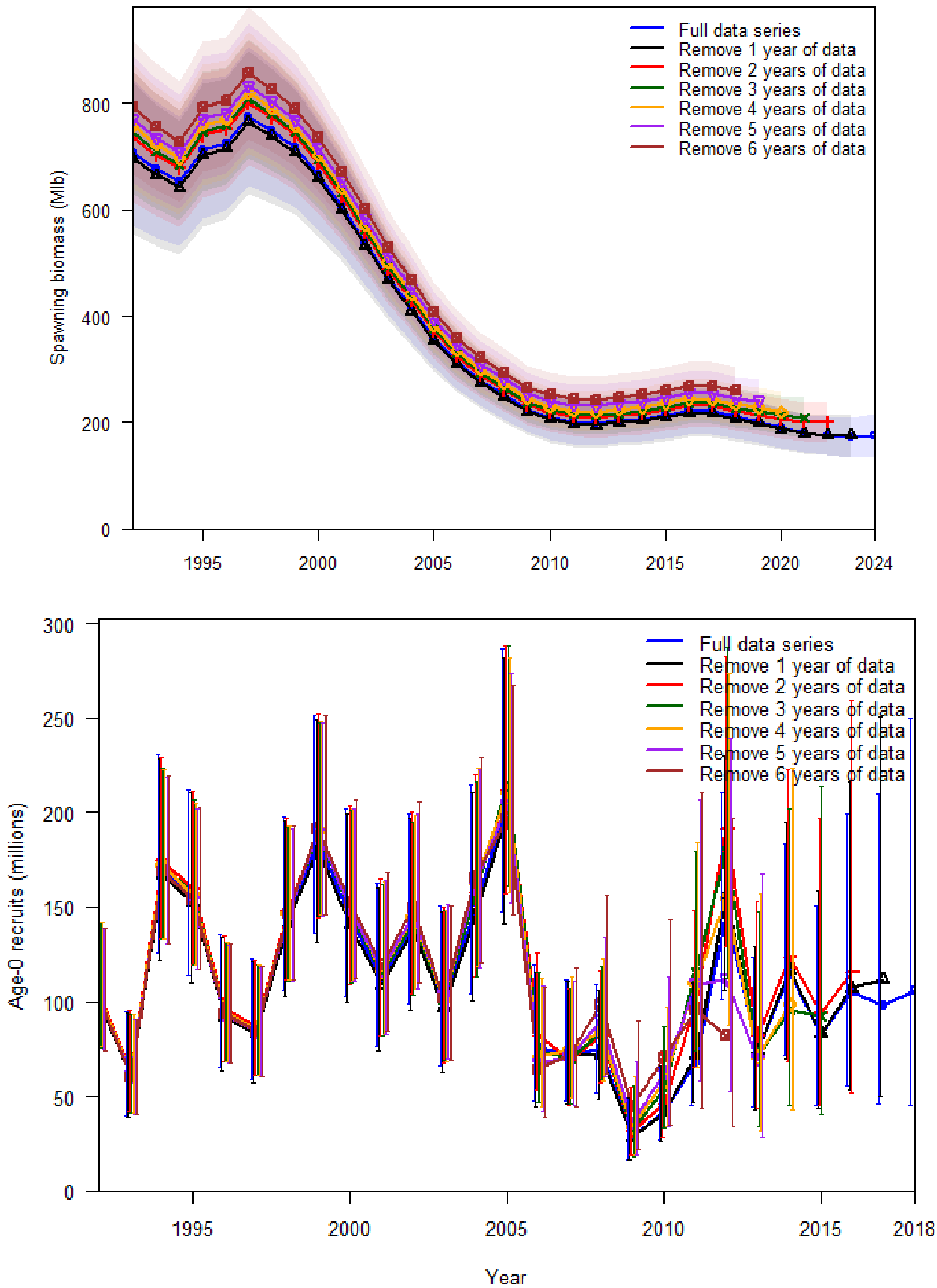

FIGURE 24. Recent spawning biomass (top panel) and recruitment (bottom panel) estimates from a retrospective analysis sequentially removing terminal years of data from the AAF long model (time series has been truncated to allow for easier inspection of terminal values). Shaded regions and vertical whiskers indicate approximate 95% within-model credible intervals.

FORECASTS AND DECISION TABLE

Short-term tactical stock projections under varying levels of mortality are conducted using the results from the 2023 stock assessment. Standard projections are based on existing Catch Sharing Agreements/Plans (CSPs) for directed commercial and recreational fisheries where they exist, as well as summaries of the 2023 and earlier directed and non-directed fisheries. Specifically, the projected mortality levels are based on the three-year running average non-directed discard mortality[3] through the most recent year (2023), per the decision during AM096 para. 97). Subsistence harvest is assumed to be constant at the most recent year's estimates. The discard mortality for the directed commercial fisheries is assumed to occur at the same rate observed in the most recent year, and to scale up or down with the projected landings.

The harvest decision table (Table 2) provides a comparison of the relative risk (in times out of 100), using stock and fishery metrics (rows), against a range of coastwide alternative harvest levels for 2024 (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)
- The mortality consistent with repeating the coastwide TCEY set for 2023 (the *status quo*)
- Bracketing alternatives 5 and 10% above and below the *status quo*
- The mortality at which there is less than or equal to a 50% chance that the spawning biomass will be smaller in 2025 than in 2024 ("*1-year surplus*")
- The mortality at which there is less than or equal to a 50% chance that the spawning biomass will be smaller in 2027 than in 2024 ("*3-year surplus*")
- The mortality consistent with the current "Reference" SPR ($F_{43\%}$) level of fishing intensity
- The mortality consistent with the Maximum Economic Yield (MEY) proxy SPR ($F_{40\%}$) level of fishing intensity
- The mortality consistent with the Maximum Sustainable Yield (*MSY*) proxy SPR ($F_{35\%}$) level of fishing intensity
- Other levels of mortality spaced between the above alternatives to provide for continuous evaluation of the change in risk across alternative yields

For each column of the decision table, the projected total fishing mortality (including all sizes and sources), the coastwide TCEY and the associated level of estimated fishing intensity projected for 2024 (median value with the 95% credible interval below) are reported.

[3] The North Pacific Fishery Management Council has adopted a new method for setting the Prohibited Species Catch (PSC) limit for Pacific halibut mortality in the Amendment 80 (A80) trawl sector in 2024. This approach adjusts PSC limits based on the NOAA Fisheries Eastern Bering Sea trawl survey and the modelled FISS index of abundance for IPHC Regulatory Areas 4A, 4B, and 4CDE. Although this new approach results in a 20% reduction to the A80 sector's PSC limit, the actual halibut mortality has been far below the aggregate PSC limit for all sectors in the Bering Sea and Aleutian Islands (59% in 2023). Therefore, it is unclear whether any future adjustments to the 3-year running average approach might be warranted, as actual mortality could still go up or down from the three year-average under current conditions. Recent actual non-directed discard mortality estimates in both IPHC Regulatory Areas 2A and 2B and in the Gulf of Alaska are similarly far below full regulatory limits.

Recent spawning biomass estimates from the 2023 stock assessment are slightly lower (11% in 2023) than those in last year's stock assessment, but the recent estimated trend is nearly flat. Updated estimates of the 2012 and 2014 year-classes (both larger than all those occurring from 2006-2011) show that these two year-classes will be highly important in the short-term stock projections as both will be maturing over the next several years. However, these two year-classes are insufficient to support short-term fishing mortality appreciably higher than the *status quo* without a decrease in spawning biomass. Risks tend to decrease slightly over the three-year period as both year-classes approach full maturity.

Projections indicate that the spawning biomass would increase relatively rapidly in the absence of any fishing mortality, with risks of stock decline over one and three years both less than 1/100 (Table 2, Figure 25). At the *status quo* coastwide TCEY (36.97 million pounds), risks of stock decrease over one and three years are 45/100. For all harvest levels that exceed the three-year surplus (39.1 million pounds) risks of stock decline are larger than 50/100, and reaching 94/100 for the coastwide TCEY that is projected to correspond to the $F_{35\%}$ *MSY* proxy harvest level in 2024. Alternative harvest levels around the *status quo* (+/- 5 and 10%) are projected to result in levels of fishing intensity ranging from $F_{54\%}$ to $F_{48\%}$, similar to those estimated for 2020-2023. At the reference level of fishing mortality ($F_{43\%}$) the 2024 coastwide TCEY is projected to be 48.9 million pounds (50.5 million pounds of mortality including U26 non-directed discard mortality). Stock decline over the next three years is projected to be very likely (72/100) at this level of fishing intensity. The probability of a reduction in the coastwide TCEY in order to maintain a fishing intensity no greater than $F_{43\%}$ over the next three years is projected to be 52/100.

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 (IPHC-2024-AM100-06).

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TABLE 2. Harvest decision table for 2024-2026 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.

		2024 Alternative			*Status quo -10%*	*Status quo -5%*	*Status quo*	*Status quo +5%*	3-Year Surplus	*Status quo +10%*		*Reference $F_{43\%}$*	*MEY proxy*	*MSY proxy*	
		Total mortality (M lb)	0.0	21.6	34.9	36.7	38.6	40.4	40.7	42.3	46.6	50.5	56.1	67.3	
		TCEY (M lb)	0.0	20.0	33.3	35.1	37.0	38.8	39.1	40.7	45.0	48.9	54.5	65.7	
		2024 fishing intensity	$F_{100\%}$	$F_{68\%}$	$F_{54\%}$	$F_{52\%}$	$F_{51\%}$	$F_{50\%}$	$F_{49\%}$	$F_{48\%}$	$F_{45\%}$	$F_{43\%}$	$F_{40\%}$	$F_{35\%}$	
		Fishing intensity interval	--	46-79%	32-68%	31-67%	29-65%	28-64%	28-64%	27-63%	25-60%	23-58%	20-55%	17-50%	
Stock Trend (spawning biomass)	in 2024	is less than 2023	<1	7	35	40	45	50	51	55	66	74	85	96	a
		is 5% less than 2023	<1	<1	7	9	12	15	15	18	26	33	44	69	b
	in 2025	is less than 2023	<1	8	35	40	45	50	50	54	65	74	84	95	c
		is 5% less than 2023	<1	2	17	20	24	28	29	32	42	51	64	85	d
	in 2026	is less than 2023	<1	10	36	40	45	49	50	54	64	72	82	94	e
		is 5% less than 2023	<1	4	23	26	30	34	35	39	49	57	69	87	f
Stock Status (Spawning biomass)	in 2024	is less than 30%	25	25	25	25	25	25	25	25	26	26	26	26	g
		is less than 20%	<1	<1	1	2	2	2	2	2	3	4	5	9	h
	in 2025	is less than 30%	21	24	25	25	25	25	25	25	25	25	26	26	i
		is less than 20%	<1	<1	2	2	2	3	3	3	5	7	9	16	j
	in 2026	is less than 30%	8	21	24	25	25	25	25	25	25	25	26	26	k
		is less than 20%	<1	<1	2	2	3	3	3	4	6	8	12	19	l
Fishery Trend (TCEY)	in 2024	is less than 2023	0	<1	25	27	28	30	31	33	41	50	63	85	m
		is 10% less than 2023	0	<1	23	25	26	27	27	29	34	41	52	75	n
	in 2025	is less than 2023	0	1	25	26	28	30	31	33	42	51	65	87	o
		is 10% less than 2023	0	<1	22	24	26	27	27	29	35	42	55	78	p
	in 2026	is less than 2023	0	1	24	26	28	30	31	33	42	52	67	88	q
		is 10% less than 2023	0	<1	21	23	25	27	27	29	35	43	57	81	r
Fishery Status (Fishing intensity)	in 2023	is above $F_{43\%}$	0	<1	26	27	29	31	32	34	42	50	62	82	s

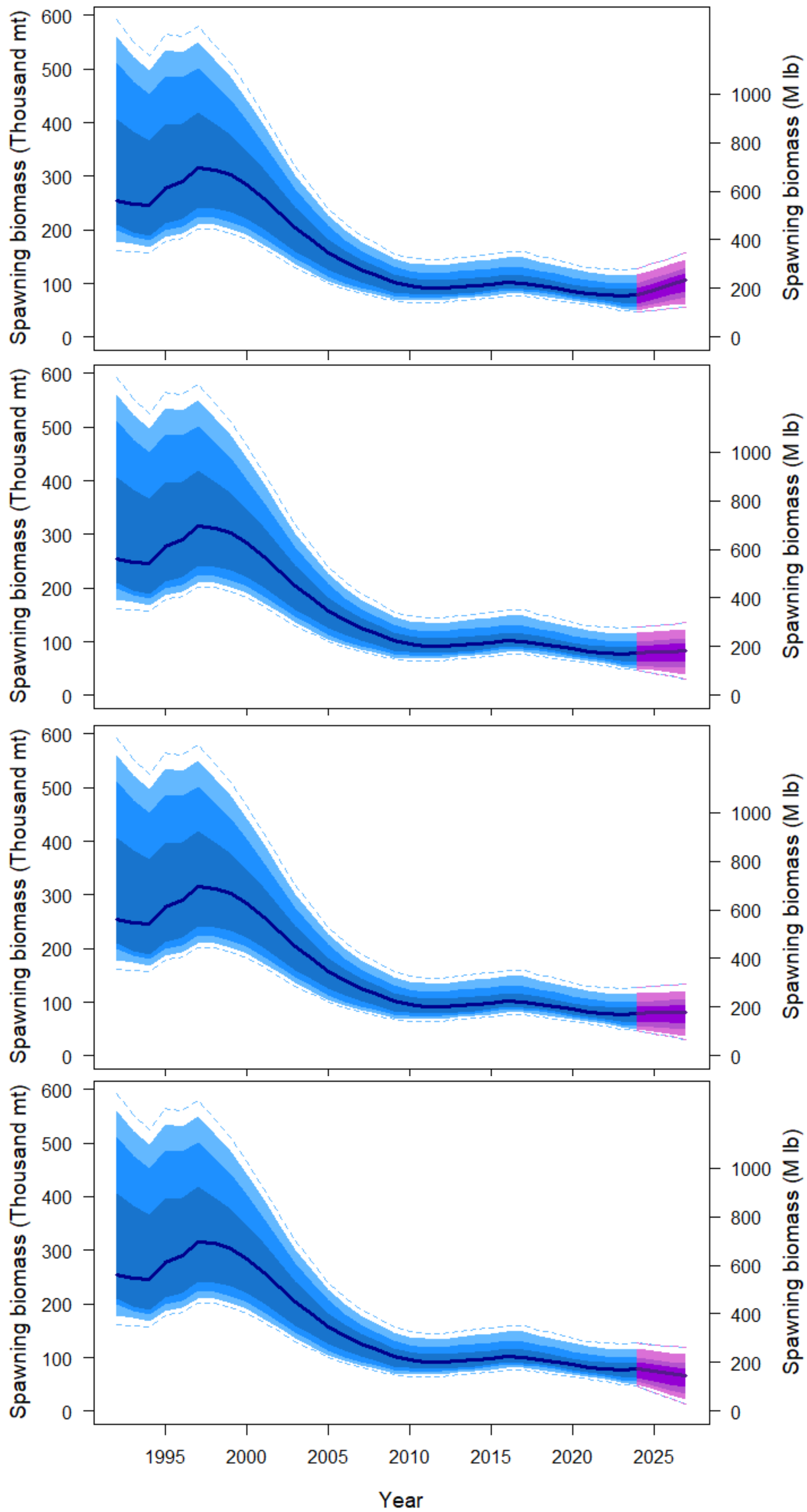

FIGURE 25. Three-year projections of stock trend under alternative levels of mortality: no fishing mortality (upper panel), the *status quo* coastwide TCEY set in 2023 (36.97 million pounds; second panel), the 3-year surplus (39.1 million pounds; third panel), and the TCEY projected for the $F_{43\%}$ reference level of fishing intensity (48.9 million pounds, fourth panel) and the TCEY projected for the $F_{35\%}$ MSY proxy level of fishing intensity (65.7 million pounds, bottom panel).

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