Development of the 2025 Pacific halibut (*Hippoglossus stenolepis*) stock assessment

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PURPOSE

To provide the IPHC's Scientific Review Board (SRB) with a response to recommendations and requests made during SRB025 (IPHC-2024-SRB025-R) and SRB026 (IPHC-2025-SRB026-R) and to provide the Commission with an update on progress toward the 2025 full stock assessment.

INTRODUCTION

The International Pacific Halibut Commission (IPHC) conducts an annual coastwide stock assessment of Pacific halibut (*Hippoglossus stenolepis*). The most recent full assessment was completed in 2022 (IPHC-2023-SA01). Following updates in 2023 and 2024, the 2025 stock assessment represents another full analysis, revisiting all data sources and structural choices. The preliminary results of this full assessment were provided to SRB026 (IPHC-2025-SRB026-07).

Starting with the final 2024 stock assessment data, models and results (Stewart and Hicks 2025b; Stewart and Webster 2025), the preliminary analysis provided a sequentially updated 'bridge' of the changes made through June 2025, including:

1) Extending the time series to include projected mortality based on limits adopted for 2025 (IPHC 2025b),
2) updating to the newest stock synthesis software version (3.30.23.1; Methot Jr 2024),
3) updating the time-series information for the Pacific Decadal Oscillation, used as a covariate to the stock-recruitment relationship,
4) retuning the constraint on the scale of male time-varying fishery selectivity (the sex-ratio of the commercial fishery) and extending this variability into the forecast,
5) improving the bootstrapping approach to pre-model calculation of maximum effective sample sizes to include ageing imprecision (Hulson and Williams 2024),
6) re-tuning the process and observation error components of these models to achieve internal consistency within each,
7) and updating the maturity ogive to reflect the recent histology-based estimates produced by the IPHC's Biological and Ecosystem Sciences Branch.

The final 2025 assessment will be produced for the IPHC's 2025 Interim (IM101) and Annual (AM102) meetings. Updated data sources, including the results of the 2025 Fishery-Independent Setline Survey (FISS), logbook and biological data from the 2025 commercial fishery, and sex-ratio information from the 2024 commercial landings-at-age will be included for the final 2025 analysis.

Starting from the preliminary stock assessment presented in June, this document focuses on addressing requests and recommendations made during SRB025 and SRB026.

SRB REQUESTS AND RECOMMENDATIONS

The SRB made a series of requests and recommendations specific to the stock assessment during SRB025 and SRB026. This section provides a response to those requests not already addressed at SRB026:

1) SRB025 (para. 20):

   *"The SRB **REQUESTED** an analysis of the relationship between commercial CPUE and the FISS WPUE at the coastwide and regional levels to investigate the strength of hyperstability/hyperdepletion in CPUE for the stock assessment in 2025. This analysis should include two scenarios: (i) the historical FISS WPUE estimates and (ii) FISS WPUE estimates calculated from reduced designs (i.e. subset the historical FISS data and recalculate WPUE from the reduced data set). The statistical model used for the analysis should account for uncertainty in the FISS index (the X-axis variable) using, for example, an error-in-variables approach like that in Harley et al. 2001 (CJFAS). This analysis represents a first step in including presumed hyperstability in scenarios that investigate the impacts of reduced FISS designs."*

2) SRB026 (para. 18):

   *"The SRB **RECOMMENDED** that the 2025 stock assessment incorporate the new maturity ogives, however, the incorporation of new fecundity information should be delayed until the next full stock assessment when more robust data and analysis of fecundity at age/weight information are available."*

3) SRB026 (para. 21):

   *"The SRB NOTED the bridging, data updates, and sensitivity analyses on the stock assessment and **RECOMMENDED** adopting those changes and moving forward with the final models presented at SRB026."*

4) SRB026 (para. 22):

   *"The SRB **RECOMMENDED** conducting a sensitivity analysis of all ensemble models to the use of a Normal (rather than Lognormal) prior distribution on natural mortality. The Normal distribution is the least informative option when an informative prior is needed."*

5) SRB026 (para. 23):

   *"The SRB **RECOMMENDED** an analysis of historical performance of the decision table metrics, i.e. a retrospective analysis of stock assessment outputs used in management advice."*

6) SRB026 (para. 24):

   *"The SRB **RECOMMENDED** that recruitment projections in the stock assessment and Management Strategy Evaluation (MSE) incorporate a random-walk starting from the most recent reliable recruitment estimate to constrain expected short-term recruitment around recent estimates rather than immediately reverting to the stock-recruitment relationship."*

7) SRB026 (para. 26):

   *"The SRB **RECOMMENDED** that a candidate state space assessment model (e.g. WHAM) be developed for Pacific halibut and presented by SRB032, tentatively scheduled for June 2028. Progress toward this modelling framework may also be presented at interim SRB meetings."*

Request 1 – Commercial and FISS CPUE

In order to better understand the spatial extent of surveys over the 32-year time series of modern FISS sampling we first summarized each annual design based on the percentage of stations sampled in each year (relative to the 1,890 stations in the full design) for each Biological Region and coastwide (Figure 1). Sampling ranged from 0% in Biological Region 4B early and late in the time series (and Biological Region 2 in 1994) to 100% in Biological Region 4B and 3 in 2017 and 2019 as the planned survey expansion was conducted across each of the IPHC Regulatory Areas. The FISS-calibrated National Oceanic and Atmospheric Administration (NOAA) and Alaska Department of fish and Game (ADFG) trawl surveys in the Bering Sea provide a strong baseline of almost two-thirds of the total stations in Biological Region 4 in all years except 2020 when the NOAA survey was cancelled due to COVID-19 precautions. Although the coverage was relatively high in Biological Region 3 for most of the time-series, some stations from the current full design had never been fished until 2019, such that there was still some potential for bias in that Region.

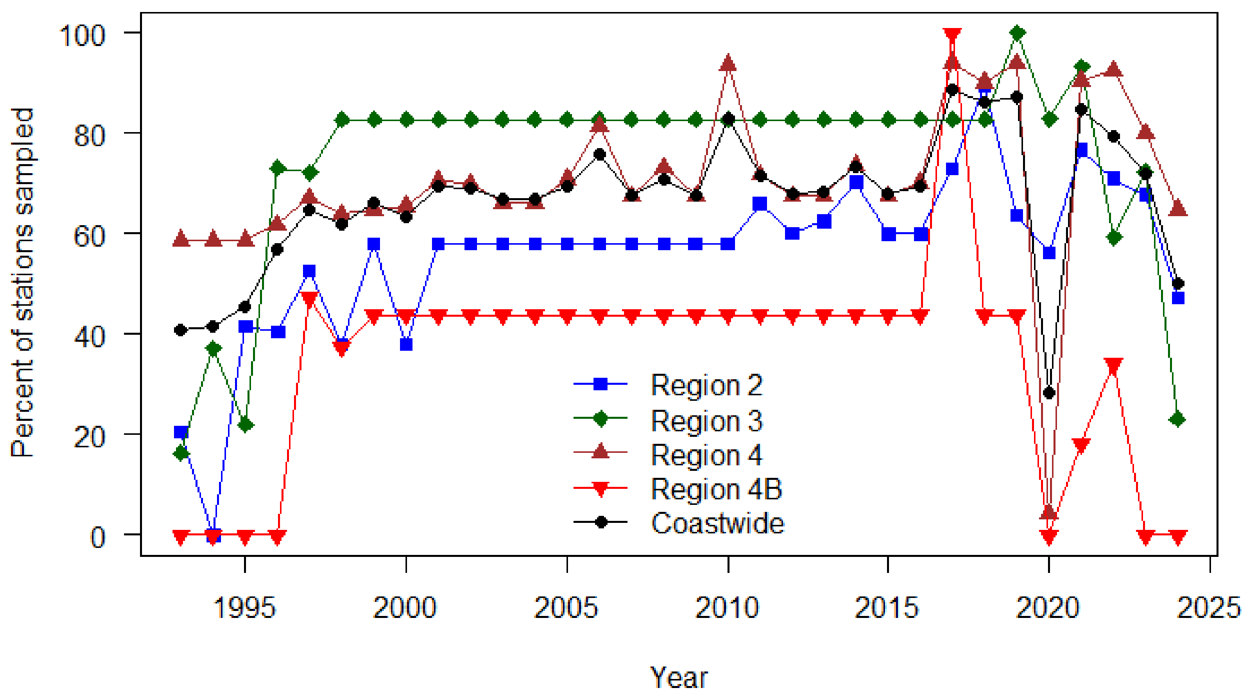

Figure 1. Annual FISS spatial coverage (as a percentage of total stations surveyed in each Biological Region and coastwide).

We divided the years into two general categories: those in which each Biological Region (or coastwide) had at least 65% coverage ('broad' suveys) and those with lower coverage ('reduced' surveys). We then compared the catch rates (Weight-Per-Unit-Effort; WPUE) of legal size Pacific halibut (O32, or over 32 inches or 81.3 cm) from the FISS to the catch rates experienced by the directed commercial longline fishery (which only lands fish above the 32 inch minimum size limit). Because the commercial fishery targets areas of higher-than-average Pacific halibut density, the raw catch rates are naturally higher than those observed in the FISS which operates on a uniform 10 nautical mile grid (Figure 2). This pattern is most pronounced in Biological Region 4 where there are broad areas of the continental shelf with very low (non-commercially viable) densities of Pacific halibut and the directed commercial fishery is concentrated on a few locations along the shelf-slope break and in areas around the few islands occurring in this Region.

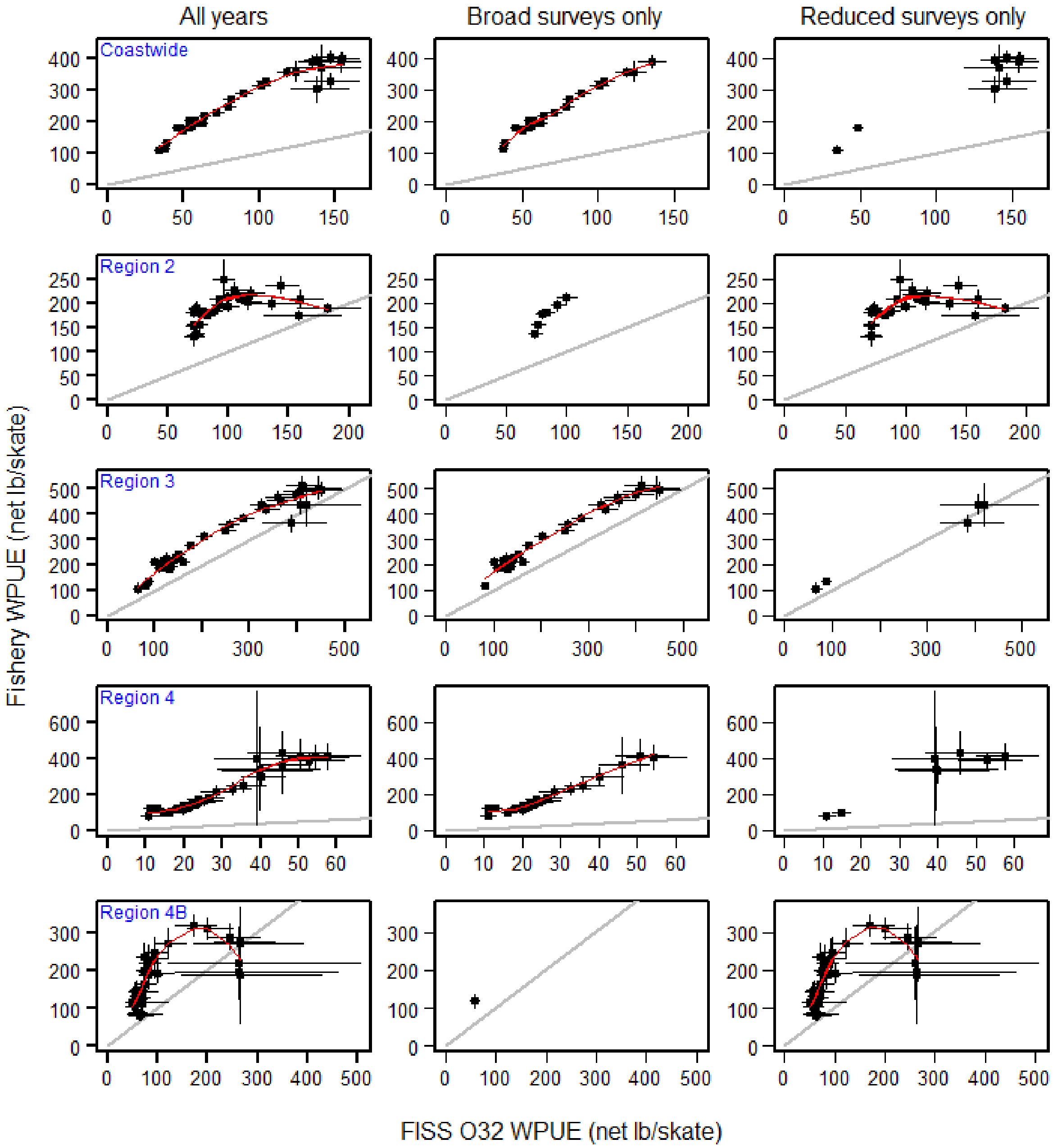

Figure 2. Relationship between FISS O32 catch rate and commercial fishery catch rate by Biological Region and Coastwide. Columns denote all years (1993-2024; left), years with at least 65% of the stations sampled (center) and years with less than 65% of stations sampled (right). Vertical and horizontal lines indicate approximate 95% credible intervals, grey diagonal line indicates a 1:1 relationship and the red lines are a loess smoother included for visualization.

We then standardized each of the catch rate time-series' by dividing each year by the mean for all years in that Region or coastwide, thereby eliminating the effects of catchability and allowing a more direct focus on the relationship between the two series (Figure 3). After this standardization it is clear that for most broad survey years there is a nearly linear relationship between FISS and commercial fishery catch rates (Figure 3, center column). For all years, and especially for years in which only reduced surveys occurred, there is a more complicated relationship between the two series. Large values, often occurring early in the time series when FISS coverage was limited, tended to show higher values for the FISS than for the commercial fishery across all areas. Smaller values with reduced surveys observed in Biological Regions 2 and 4B tended to show a steeper slope (relatively lower values for the commercial fishery than for the FISS). As it is unclear whether the FISS or the commercial fishery more closely reflects the underlying population when surveys were reduced it is difficult to delineate between potential hyperstability or hyperdepletion in one or both indices.

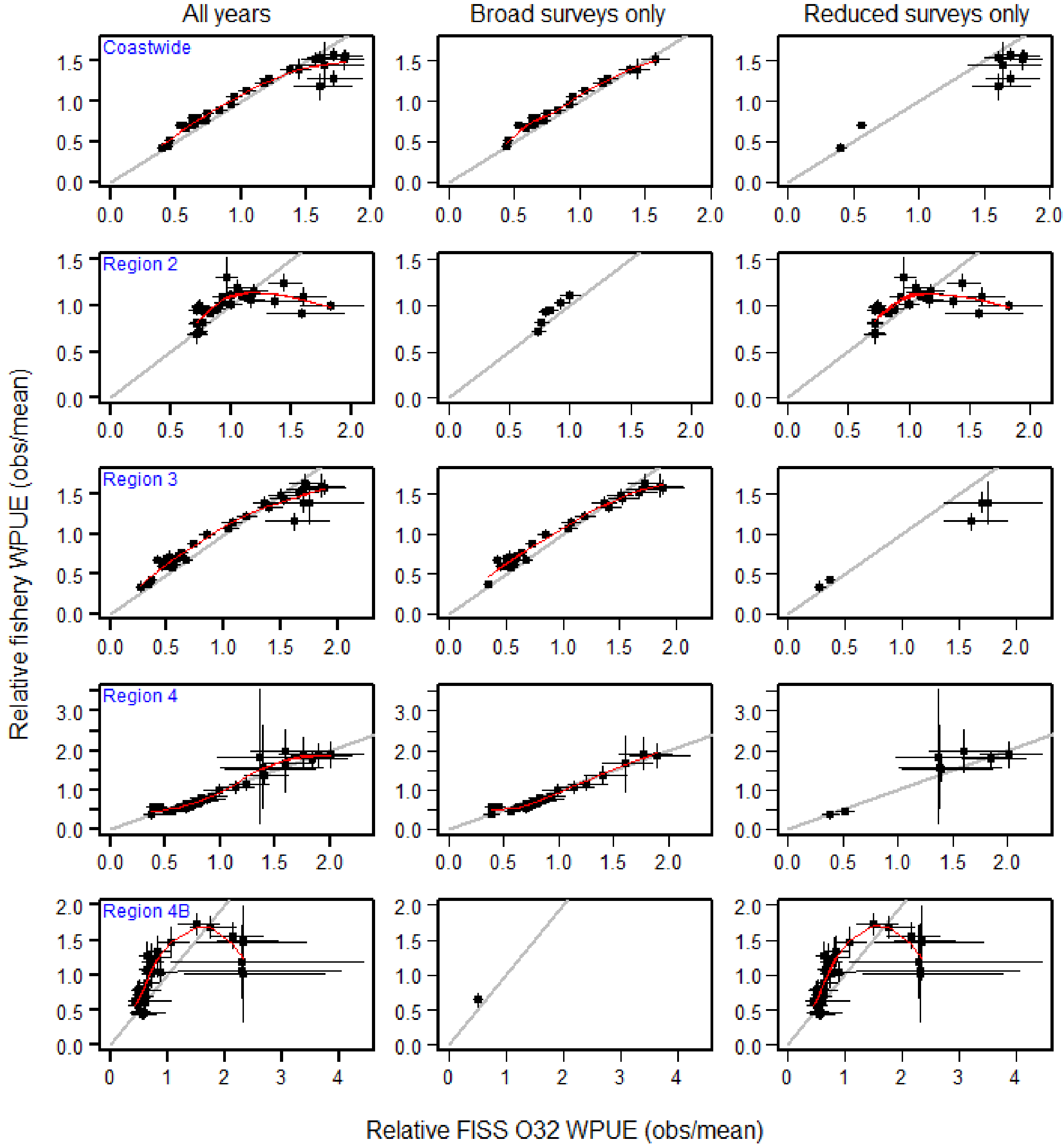

Figure 3. Identical to figure 2, except that FISS and commercial fishery catch rates have been divided by the mean across the entire time-series for that Biological Region and coastwide to account for absolute differences in catchability.

The patterns observed in this comparison are consistent with the somewhat conflicting signal in recent fishery and FISS trends, where the fishery catch-rate has shown a greater decrease than the FISS. Additional investigation of this topic is possible; however, it is unclear how to reconcile the fundamental uncertainty about which series is more reliable, especially at low observed densities and with a reduced FISS. Factors other than population trends, including whale depredation, bycatch of non-target species (e.g., Forrest et al. 2020) and shifts between targeted hook and line fishing for Pacific halibut and sablefish continue to create uncertainty in the commercial time-series, further strengthening the need for broad FISS spatial coverage.

Recommendations 2 &3 – Maturity, fecundity, and bridging

As requested, the updated maturity relationship presented at SRB026 is included in the 2025 stock assessment along with all bridging improvements. Emerging fecundity analyses will be evaluated during 2026-27 but are not planned for inclusion in the stock assessment until the full assessment scheduled for 2028. This will allow a re-analysis of the maturity relationship with additional data, inclusion of estimated skip-spawning, along with an updated fecundity relationship to be considered together as a comprehensive evaluation of reproductive capacity of the Pacific halibut stock.

Recommendation 4 – Sensitivity to priors on natural mortality

Since the 2022 full stock assessment, all four models have used a log-normal prior on natural mortality for both females and males aged 3+. This age independent prior on M was developed based on published meta-analyses (Hamel 2014; Hamel and Cope 2022), which uses the prediction interval based on a meta-analysis of the maximum observed age for a wide range of species. This approach serves as a standard prior for many North Pacific groundfish species. Both male and female Pacific halibut have been observed to age-55 (with multiple fish of both sexes exceeding age-50 indicating that this is likely to be an accurate estimate of longevity, and not an artifact of a single case of ageing imprecision). The prior median is given by:

$$M = \frac{5.4}{Age_{max}}$$

which results in a value of 0.0982, and a log(SD) of 0.438. With such a large variance, this prior is only weakly informative, but still may provide some stability for estimation of *M*.

To explore the sensitivity of current models to this choice, two alternative priors were explored: uniform over a relatively broad range of values (0.02-0.25), and a normal prior with the same expectation (0.0982) and SD tuned to approximate the upper 95th quantile from the lognormal (Figure 4).

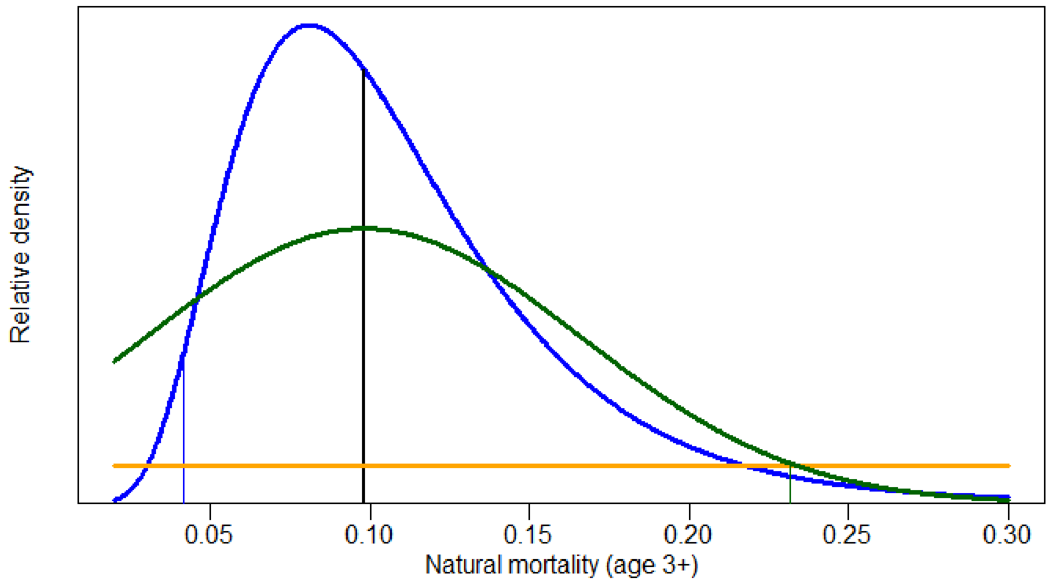

Figure 4. Three alternative priors on natural mortality: lognormal (blue), normal (green) and uniform (orange). Lognormal and normal priors both have a median value of 0.0982 (vertical black line) and identical upper 95% intervals. To facilitate visual comparison, probability density functions are scaled independently for all three distributions.

Each of these three priors was used in alternative configurations for each of the four stock assessment models. For the coastwide short model, neither the uniform or the normal prior stabilized the estimate of M below the upper bound (Figure 5), the same behavior previously identified for the log-normal prior in the preliminary assessment presented in June. For the other three models the lognormal and normal priors generally resulted in similar maximum likelihood estimates and scaling of the spawning biomass and recruitment (Figures 6-8). Even the uniform prior did not lead to an appreciably different estimate of M in any of the three models where it is not fixed, however it was slightly higher in the coastwide long model leading to a slightly larger scale of the spawning biomass and recruitment in that case (Figure 7).

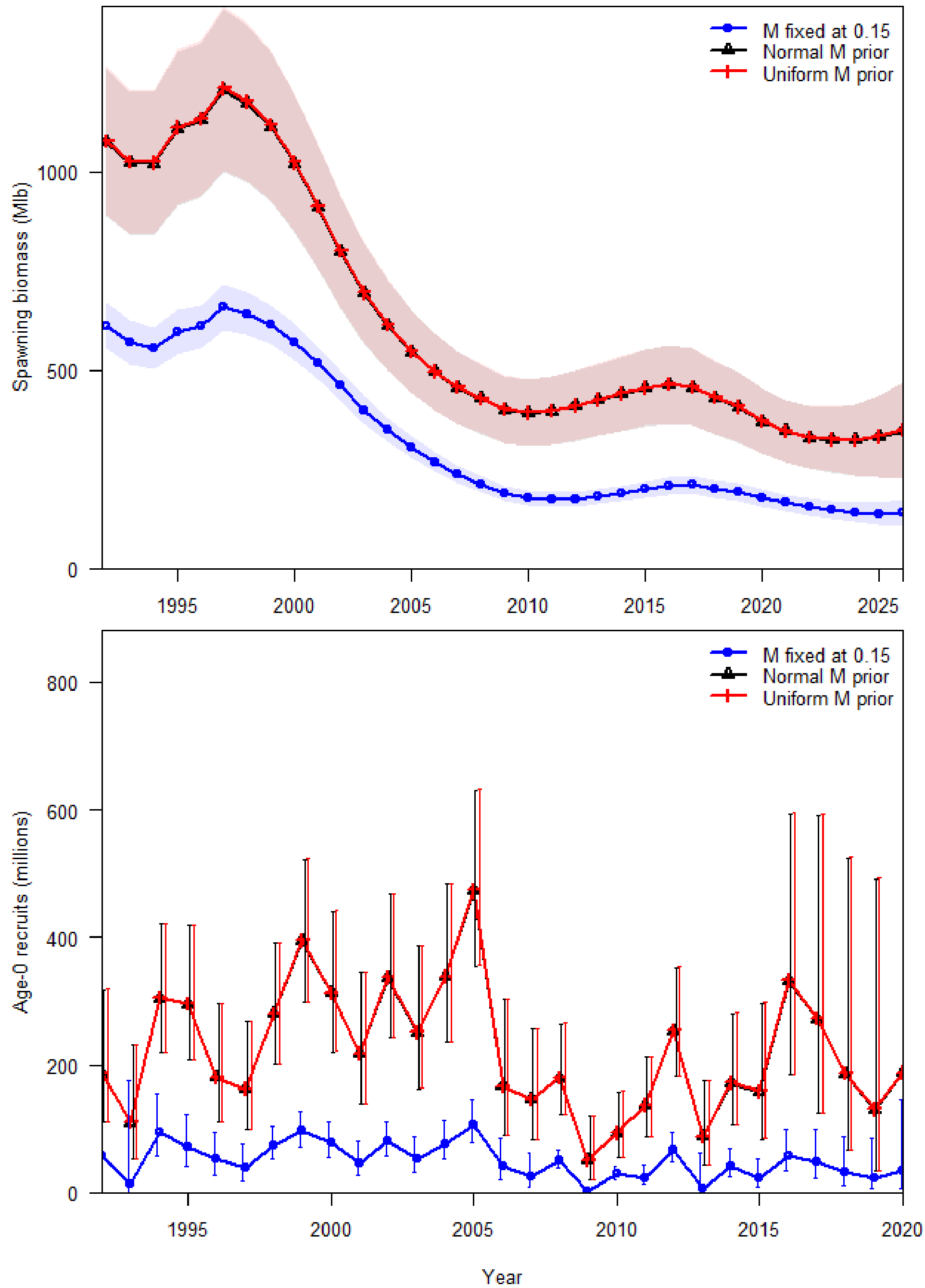

Figure 5. Time series of estimated spawning biomass (upper panel) and recruitment (lower panel) based on three alternative priors for natural mortality applied to the coastwide short model. Note that the maximum likelihood value for M was at the upper parameter bound of 0.25 when estimation was attempted with both priors in this model.

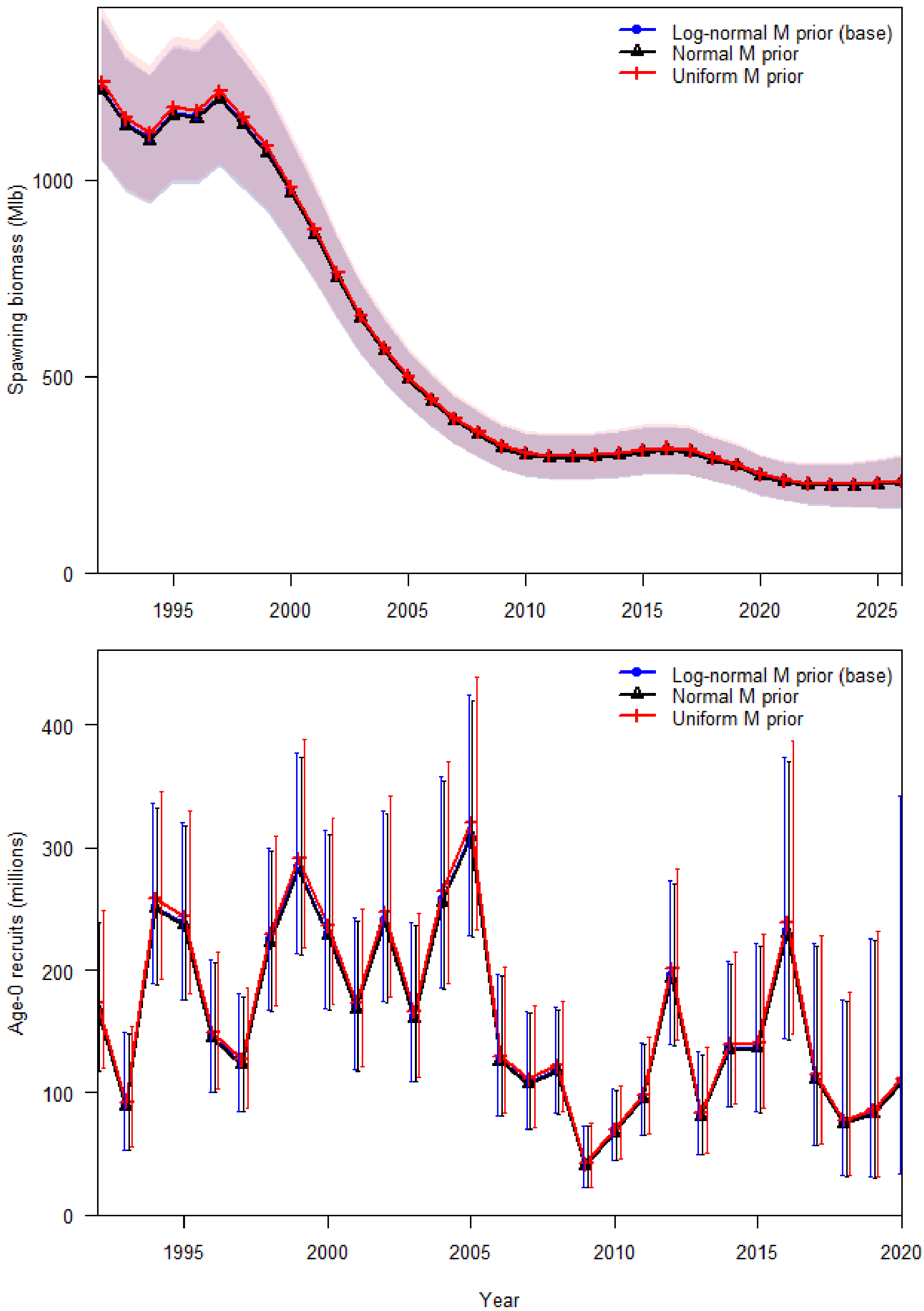

Figure 6. Time series of estimated spawning biomass (upper panel) and recruitment (lower panel) based on three alternative priors for natural mortality applied to the AAF short model.

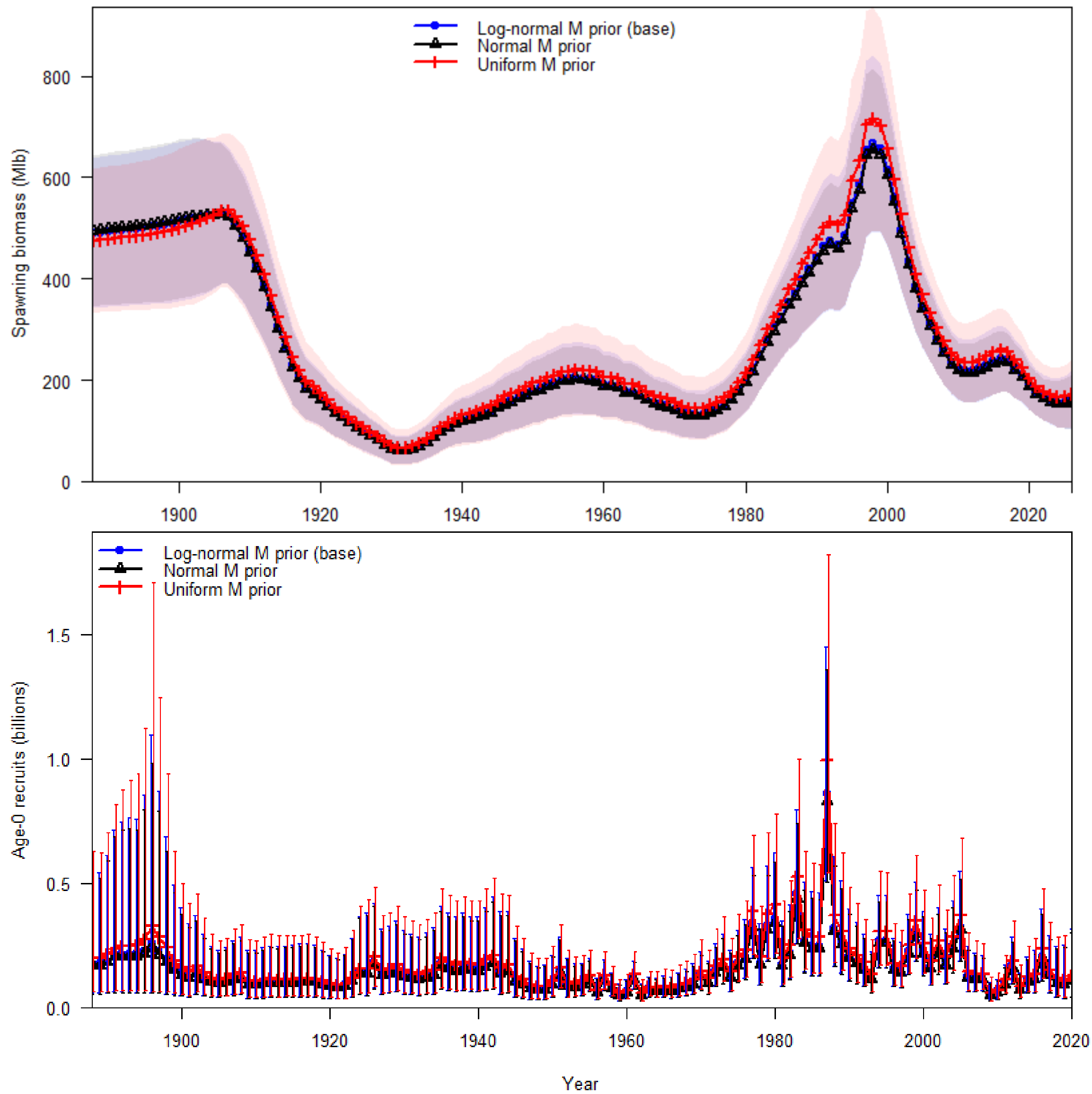

Figure 7. Time series of estimated spawning biomass (upper panel) and recruitment (lower panel) based on three alternative priors for natural mortality applied to the coastwide long model.

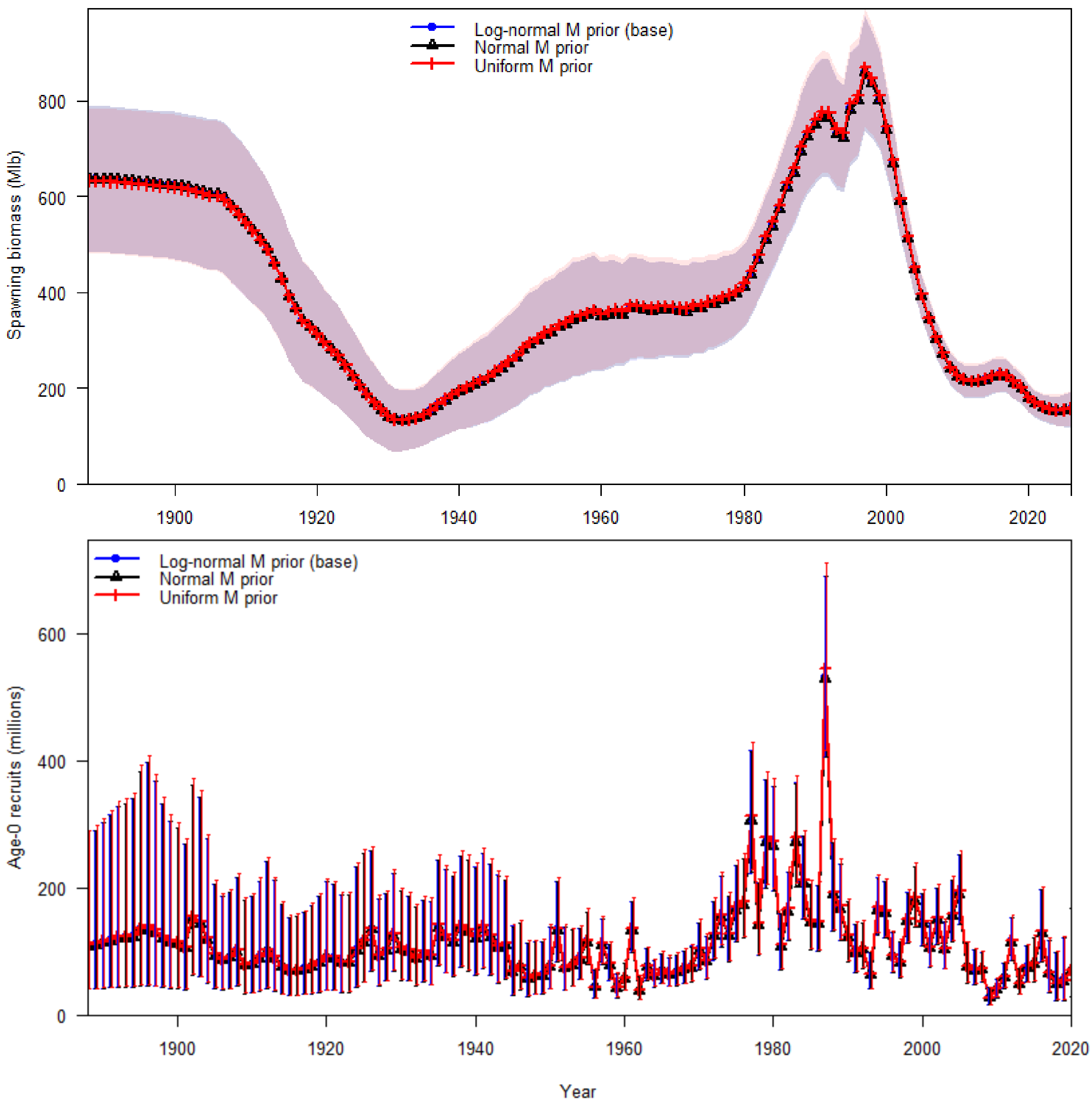

Figure 8. Time series of estimated spawning biomass (upper panel) and recruitment (lower panel) based on three alternative priors for natural mortality applied to the AAF long model.

Recommendation 5 – Retrospective evaluation of management information

The spawning biomass ('stock') trend has been the focus of considerable discussion at IPHC Annual meetings since a decision table-based approach was first introduced as part of the 2013 stock assessment. Each year, the probability of stock decline in the upcoming year, along with the probability of stock decline of at least 5% is estimated and provided for a range of alternative harvest levels. Discussion among stakeholders often includes reference to the probability of stock decline as a function of the selected mortality limits. Although the probability of stock decline is always reported as a 'risk', there is a corresponding probability of stock increase (or decline of less than 5%, which includes increases) that, along with the probability of decline, always sums to 100% for each projection. These two key decision table outputs were summarized for all assessments from 2013 through 2024 for comparison with actual estimated trends in the spawning biomass based on the 2024 final stock assessment results. For each year, either stock decline or stock increase (including declines less than 5% for that case) is the 'actual' result which can be compared to the estimated probabilities from the year before. As there is never a zero probability of one outcome or the other, the decision table cannot be considered 'wrong' or 'right'; however, if the probabilities are frequently heavily in favor of outcomes that did not subsequently occur one might infer that there is room for improvement in the estimation process.

The stock increased over 2013-2016, declined over 2017-2023 and then increased in 2024. The annual decision table generally favored a higher probability for stock increase/decrease when that was the subsequent outcome (Figure 9). In no years did the stock either actually increase or decrease with less than at least a 16% probability estimated for that outcome.

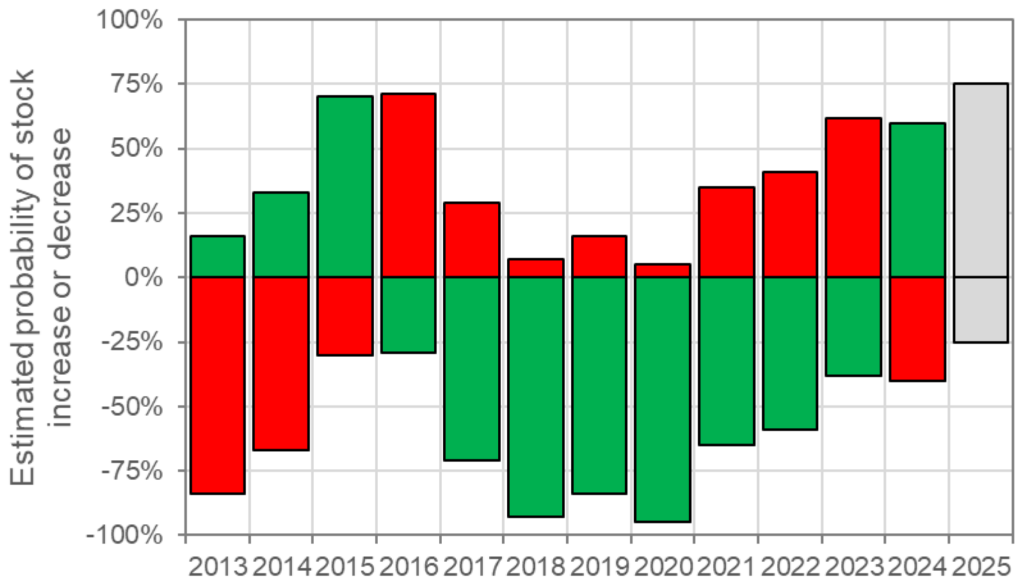

Figure 9. Time series of decision table projections for one year ahead probabilities of: stock decrease (lower half of the graph) or stock increase (upper half of the graph). Green bars indicate the actual (correct) stock trend in each year, red bars indicate probabilities corresponding to incorrect trends; green and red bars sum to 100% in each year. Grey bars in 2025 denote unknown actual stock trend.

The stock is estimated to have decreased by at least 5% over the period 2017-2021 and either increased or decreased by less than 5% in all other years. Estimated probabilities of at least a 5% stock decline were higher in years of actual stock decline of more than 5% for all years except 2022 (Figure 10). The least probable outcome occurred in 2017, the first year of stock decline greater than 5%, when it was estimated to have a 10% probability. In six of the years when the stock did not decline by at least 5% the estimated probabilities favored the actual outcome with at least a 90% probability. The maximum actual estimated decline (in 2018) was only 8%, so it is difficult to determine whether a more meaningful decline might have been forecast with greater skill.

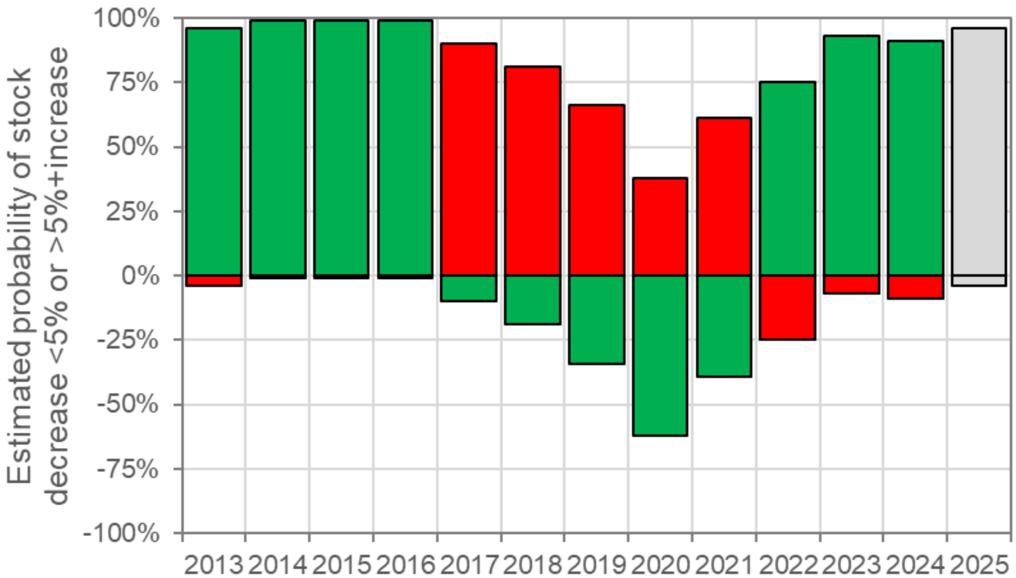

Figure 10. Time series of decision table projections for one year ahead probabilities of: stock decrease of at least 5% (lower half of the graph) or stock decrease of less than 5% or stock increase (upper half of the graph). Green bars indicate the actual (correct) stock trend in each year, red bars indicate probabilities corresponding to incorrect trends; green and red bars sum to 100% in each year. Grey bars in 2025 denote unknown actual stock trend.

Recommendation 6 – Recruitment projections

The annual stock assessment is used to produce projections extending three years into the future. This time frame was selected to minimize the impact of recruitment estimates at the end of the time series (largely uninformed by actual data) on the projected spawning biomass. The basis for the choice of three years is that maturity begins to increase rapidly at eight years old, and the FISS encounters an increasingly larger proportion of fish over ages five through eight. Therefore, fish that are five in the terminal year of the model will be only partially mature at age eight at the end of the projection period. These same fish would be an increasing component of the projected spawning biomass ages 9+ if the projection were extended to four or more years.

The approach applied in recent stock assessments for forecast recruitments has been to separate the ‘main’ recruitment vector from the more poorly informed ‘forecast’ recruitment vector based on the relative variance among the deviations compared to the average estimated variance of the deviations (Methot and Taylor 2011). Briefly, this method identifies where the variance of the recruitment deviations begins to increase rapidly at the end of the time series (usually several years before the actual last year of data; in this case approximately four years before the terminal year of the assessment). Deviations after this point are estimated in a separate ‘forecast’ vector that is not constrained to be centered on the stock-recruitment relationship (Methot Jr 2024). This ensures that deviations with little data informing them are not adjusted by the model simply to ‘balance’ the stock-recruitment function. In the case of the current Pacific halibut models including data through 2024 the forecast recruitment deviations were started in either 2015 or 2016.

The Stock Synthesis software provides for several options to adjust forecast recruitments independently from the stock-recruitment relationship. However, in the current version these options only apply to forecast recruitments occurring after the end of the time series (for the preliminary 2025 stock assessment this is in year 2025). Therefore, to explore the effects of alternative forecast recruitment assumptions on the three-year spawning biomass projections used for management, each of the four stock assessment models was adjusted to extend the main recruitment deviation vector to 2025; noting that especially in the short time series models this could result in balancing of the deviations occurring after the signal from the data but before the end of the time series (2015-2024). After extending the main recruitment deviation vector, two alternative recruitment assumptions were compared: a ‘low recruitment’ scenario, setting the forecast recruitment central tendency equal to the average observed over 2006-2015, and a ‘high recruitment’ scenario setting the forecast recruitment central tendency to the average observed over 1994-2005.

Extending the main recruitment vector through 2025 had little effect on the estimated recruitments in either of the long time-series models (Figures 11 & 12). Although the average recruitment differed substantially during the low and high periods, these fish do not mature during the forecast period and so do not affect the spawning biomass projections. For the two short time series models extending the main recruitment vector resulted in lower recruitments estimated over the period after 2016 due to balancing of the vector on the stock recruitment relationship (Figures 13 & 14). In the case of the coastwide short model, the recruitments between 2018 and 2025 were all pushed to unrealistically low values. However, although unsuitable as an actual assessment run, this alternative can still be used to compare the effects of the differing recruitment projections. The spawning biomass for both the high and low recruitment projections again did not differ, due to the fact that these recruitments do not mature during the three year projection.

Based on this evaluation, inclusion of autocorrelation in the forecast recruitments would not have an effect on the tactical stock assessment results that only extend three years into the future. Further, the use of the stock recruitment relationship as the central tendency does not lead to a rapid change in recruitment at the end of the time-series. We therefore conclude that alternative treatment of recruitment, either through inclusion of autocorrelation or productivity regimes is best explored through the Management Strategy Evaluation and not through the tactical stock assessment.

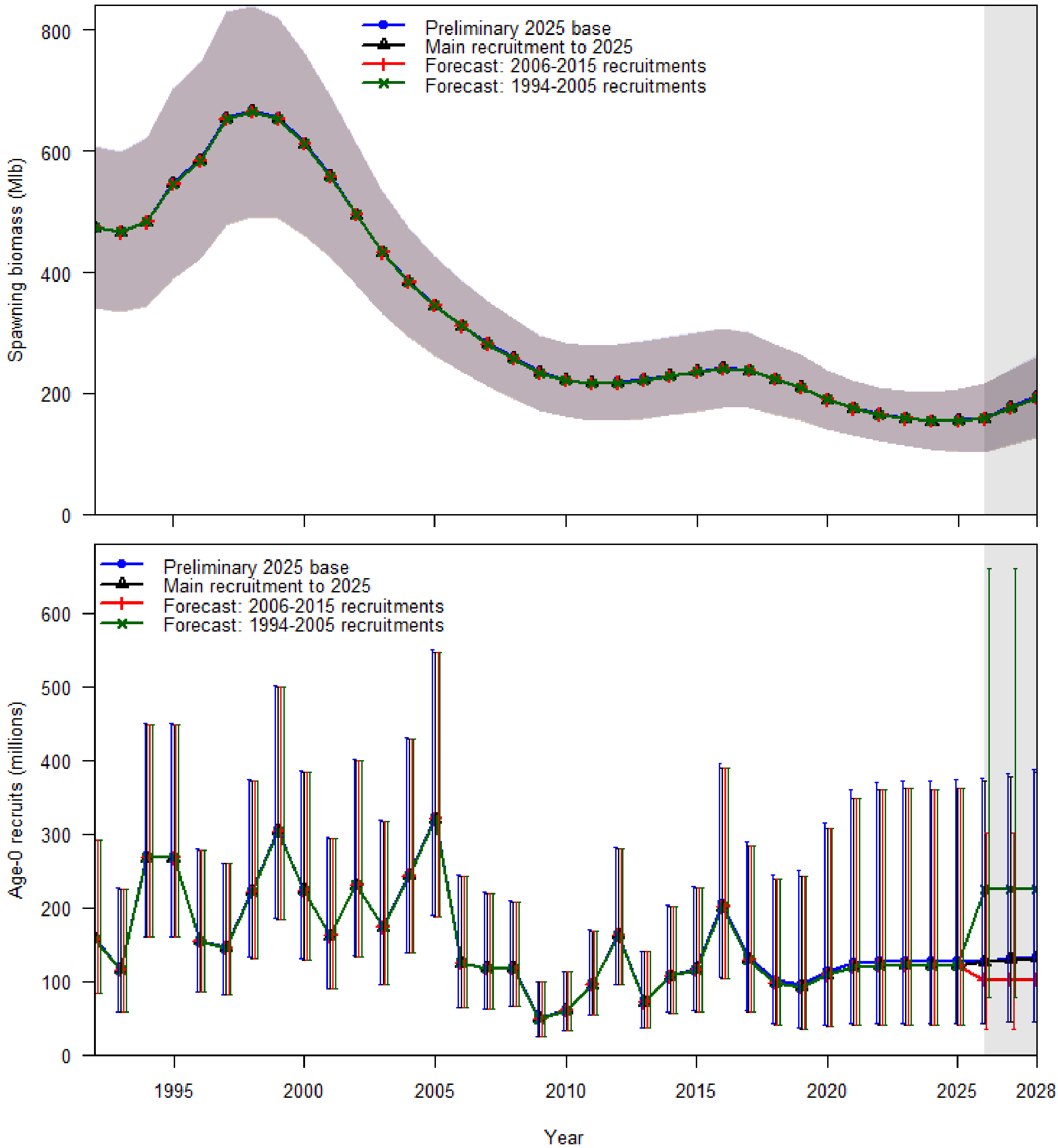

Figure 11. Recent time series of estimated spawning biomass (upper panel) and recruitment (lower panel) based on alternative recruitment projections applied to the coastwide long model. The forecast years are denoted by the shaded area.

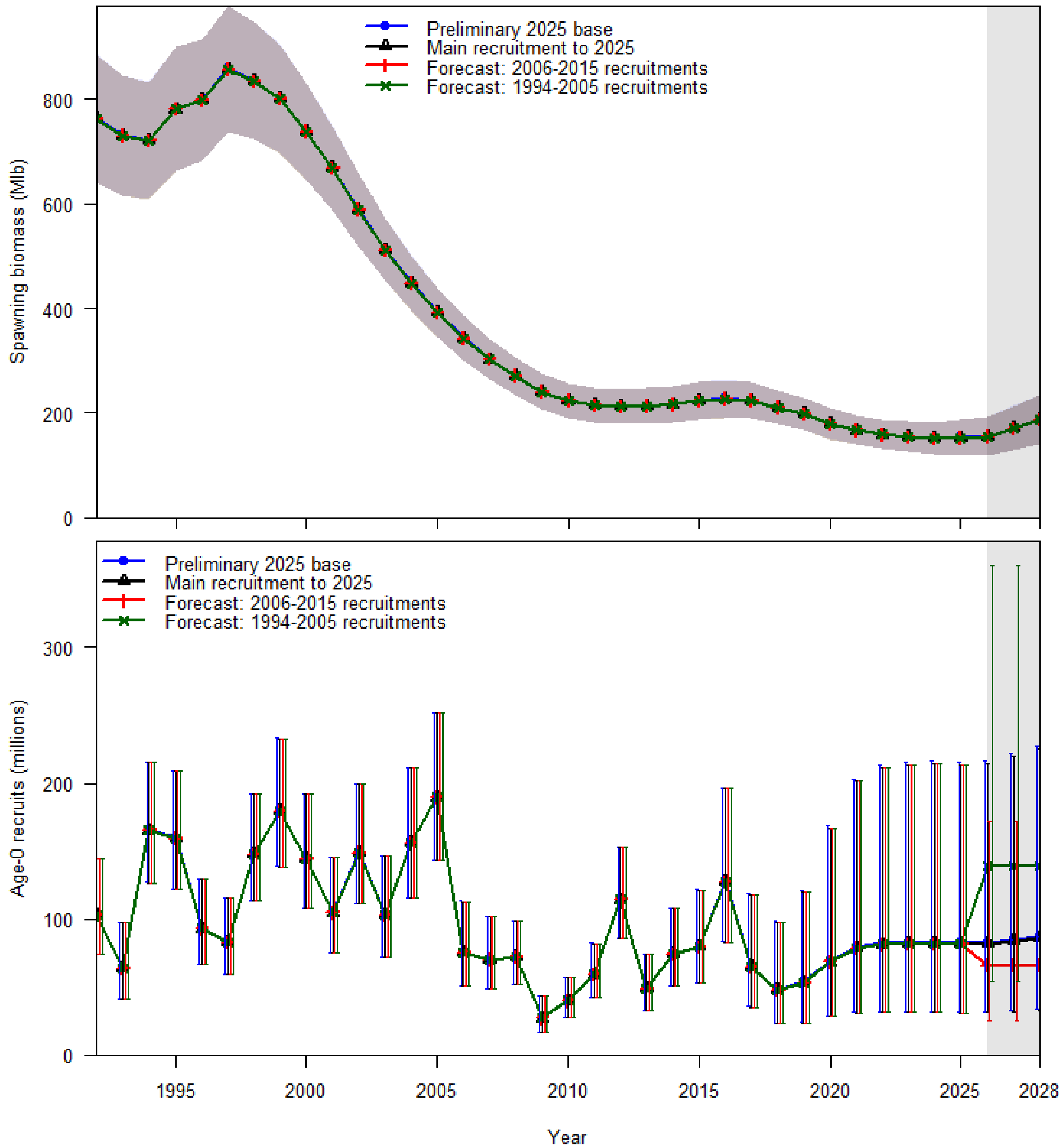

Figure 12. Recent time series of estimated spawning biomass (upper panel) and recruitment (lower panel) based on alternative recruitment projections applied to the AAF long model. The forecast years are denoted by the shaded area.

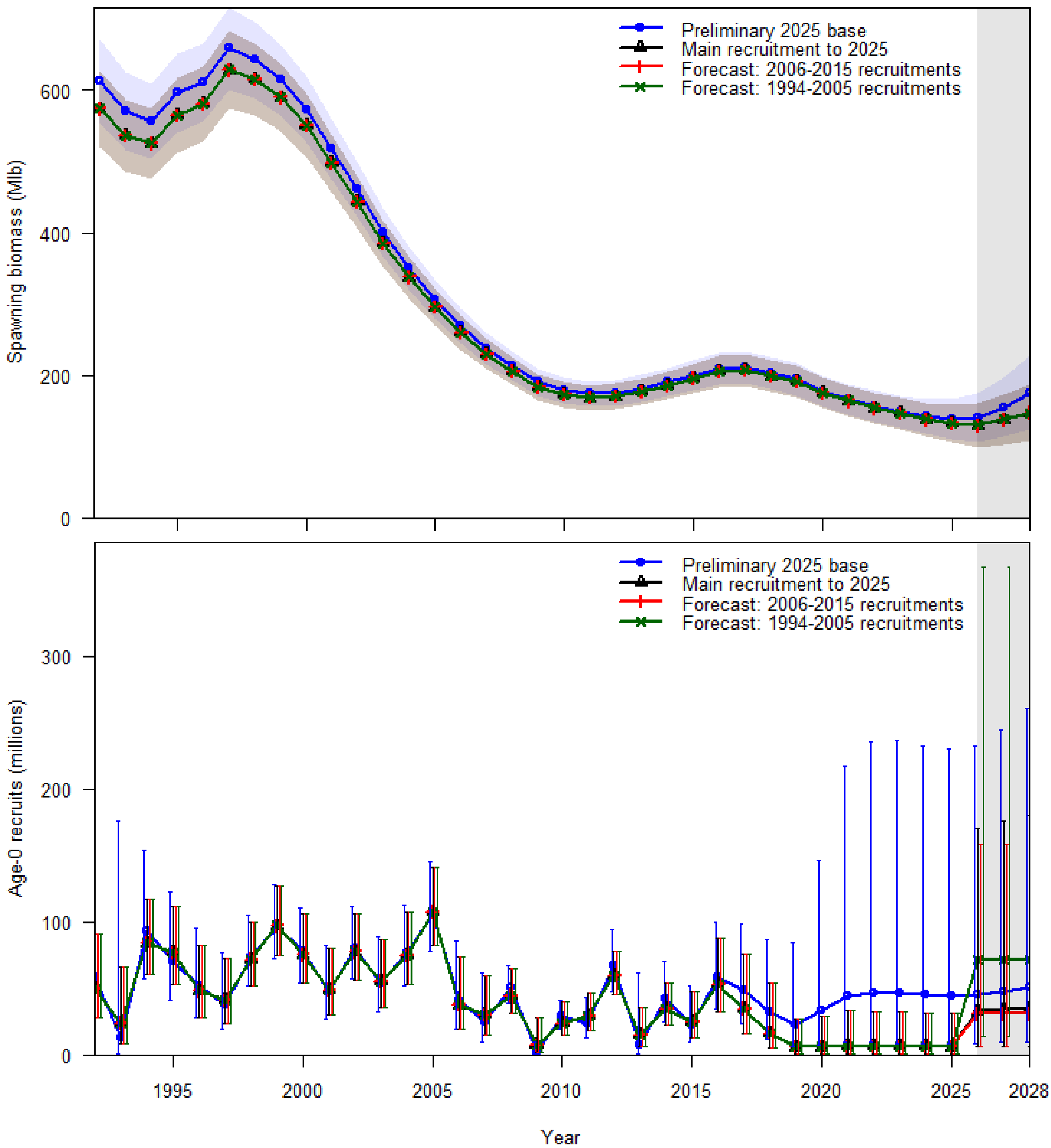

Figure 13. Time series of estimated spawning biomass (upper panel) and recruitment (lower panel) based on alternative recruitment projections applied to the coastwide short model. The forecast years are denoted by the shaded area.

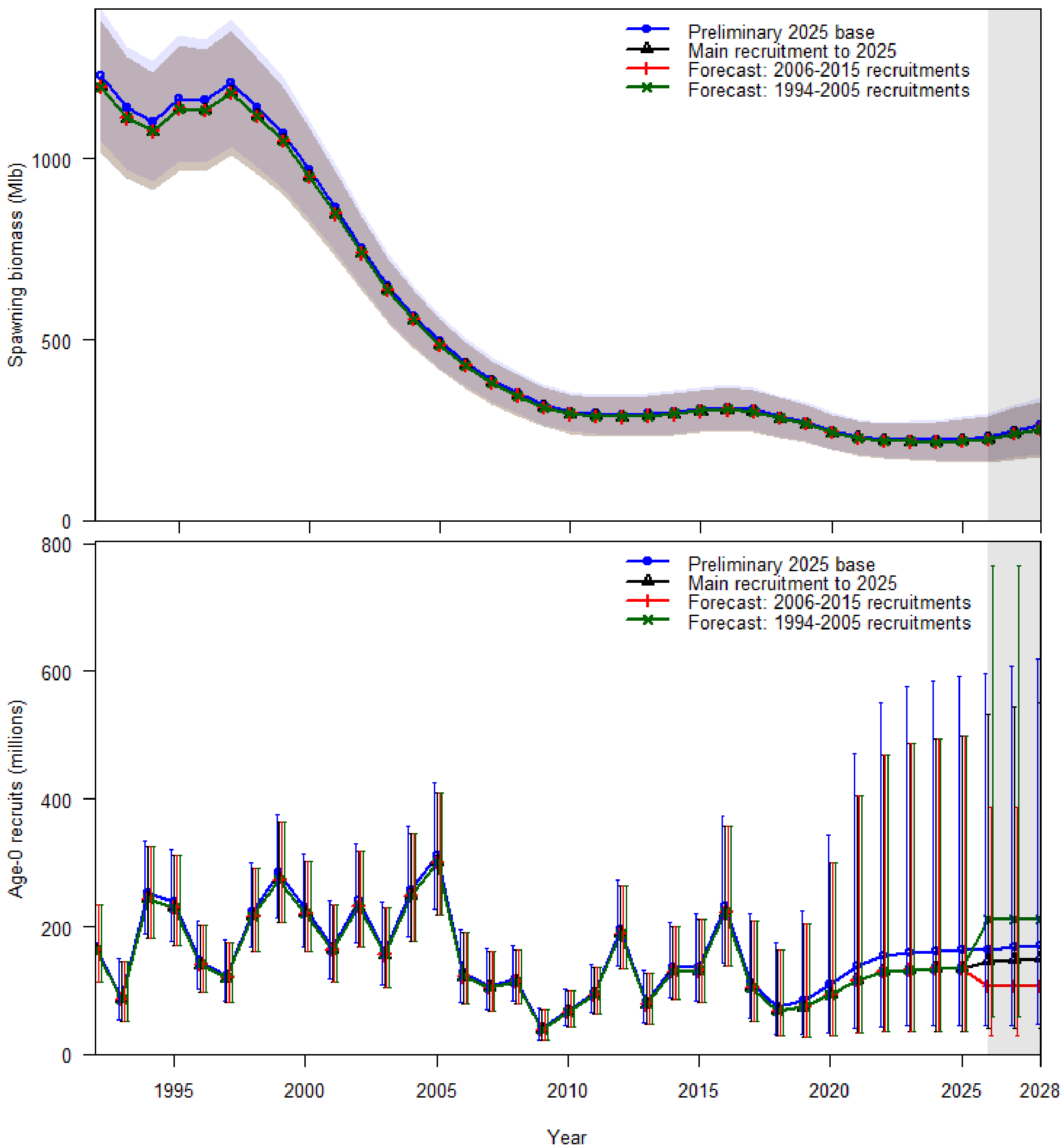

Figure 14. Time series of estimated spawning biomass (upper panel) and recruitment (lower panel) based on alternative recruitment projections applied to the AAF short model. The forecast years are denoted by the shaded area.

Recommendation 7 – Exploration of a state-space model

Progress toward the development of a state-space model for Pacific halibut will begin after this year's stock assessment has been completed.

ADDITIONAL STOCK ASSESSMENT DEVELOPMENT FOR 2025

Per standard procedures for final stock assessment preparation, the following data sources that will be included in the final 2025 stock assessment include:

1) New modelled trend information from the 2025 FISS for all IPHC Regulatory Areas.
2) Age, length, individual weight, and average weight-at-age estimates from the 2025 FISS.
3) Directed commercial fishery logbook trend information from 2025 (and any earlier logs that were not available for the 2024 assessment) for all IPHC Regulatory Areas.
4) Directed commercial fishery biological sampling from 2025 (age, length, individual weight, and average weight-at-age) and sex-ratio-at-age information from the 2024 biological samples from all IPHC Regulatory Areas.
5) Biological information (lengths and/or ages) from non-directed discards (all IPHC Regulatory Areas) and the recreational fishery (IPHC Regulatory Area 3A only) from 2024. The availability of these data routinely lags one year.
6) Updated mortality estimates from all sources for 2024 (where preliminary values were used) and estimates for all sources in 2025.

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2025-SRB027-07, which provides a response to requests from SRB025 and SRB026, and an update on model development for 2025.

b) **REQUEST** any modifications for the final 2025 stock assessment.

c) **REQUEST** any analyses to be provided at SRB028 as part of the development of the planned 2026 update stock assessment.

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