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# STOCK ASSESSMENT OF ALBACORE TUNA IN THE NORTH PACIFIC OCEAN IN 2026

**WCPFC-SC22-2026-SA-WP08_Rev02**
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**Submitted by ISC[1]**

[1] International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

# ANNEX 08

*26th Meeting of the*
*International Scientific Committee for Tuna*
*and Tuna-Like Species in the North Pacific Ocean*
*Taipei City, Chinese Taipei*
*22-29 June 2026*

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## June 2026

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## REPORT OF THE ALBACORE WORKING GROUP

**International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean**


**22- 29 June 2026**

**ISC Plenary Meeting in Taipei City, Chinese Taipei**

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# LIST OF ACRONYMS

| | |
|---|---|
| $14\%SSB_{current, F=0}$ | 14% of the current, dynamic SSB under zero fishing. Current limit reference point for North Pacific albacore tuna. |
| $30\%SSB_{current, F=0}$ | 30% of the current, dynamic SSB under zero fishing. Current threshold reference point for North Pacific albacore tuna. |
| ALBWG | Albacore Working Group of the ISC |
| ASPM | Age-structured production model, which is used for model diagnostics |
| CPUE | Catch-per-unit-effort |
| CV | Coefficient of variation |
| EPO | Eastern Pacific Ocean |
| IATTC | Inter-American Tropical Tuna Commission |
| ISC | International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (https://isc.fra.go.jp/) |
| $F_{\%SPR}$ | Instantaneous fishing mortality at age |
| $F45_{\%SPR}$ | Fishing intensity in %SPR |
| F45%SPR | Fishing intensity that results in the population reaching an SPR of 45% at equilibrium. Current target reference point for North Pacific albacore tuna. |
| JPLL | Japanese longline |
| JPPL | Japanese pole-and-Line |
| LRP | Limit reference point |
| MASE | Mean Absolute Scaled Error |
| MSY | Maximum Sustainable Yield |
| RFMO | Regional Fisheries Management Organization |
| SPR | Spawning Potential Ratio, which is the ratio of the equilibrium SSB per recruit that would result from an F-at-age relative to that of the unfished population. |
| SS | Stock Synthesis |
| SSB | Spawning Stock Biomass |
| ThRP | Threshold reference point |
| TRP | Target reference point |
| USA | United States of America |
| WCPFC | Western and Central Pacific Fisheries Commission |
| WCPFC NC | Northern Committee of the Western and Central Pacific Fisheries Commission |
| WCPO | Western and Central Pacific Ocean |

# ACKNOWLEDGEMENTS

The 2026 stock assessment of north Pacific albacore tuna is the result of a collaborative effort of the ALBWG. Members of the ALBWG who contributed to this assessment include Sarah Hawkshaw (Chair), Yuichi Tsuda (Vice Chair), Yoshinori Aoki, Yi-Jay Chang, Hirotaka Ijima, Peter Kuriyama (Lead Modeler), Naoto Matsubara, Steve Teo, Zi-Wei Yeh, and Haikun Xu.

# EXECUTIVE SUMMARY

## Stock Identification and Distribution

For stock assessment purposes, North Pacific albacore tuna (*Thunnus alalunga*) are assumed to constitute a single stock distributed throughout the Pacific Ocean north of the equator from to 0°N to 55°N. The assessment incorporates all available fishery data from this area and uses a fleets-as-areas modeling approach. Population dynamics are represented under the assumption that there is instantaneous mixing of albacore across the modeled stock area on a quarterly time step, i.e., a single, well-mixed population with no explicit internal spatial structure.

## Major changes from the 2023 assessment

There were four main changes to the base case model compared to the previous assessment in 2023. 1) The F10 JPLL index was recalculated with data from 1996-2024 and an expanded area that matched the spatial definitions in the stock assessment rather than that defined in the historical Japanese longline data. 2) Two JPLL fleets for juvenile and adult fleets (i.e., F1 and F2) in the 2023 assessment were combined into one fleet here (F1 in 2026 assessment) and modeled with time-varying age-based selectivity because having two fleets in the 2023 assessment did not improve fits to the size data and did not remove the need for time-varying selectivity. 3) Time-varying age-based selectivity was estimated with two-dimensional autoregressive selectivity patterns rather than assuming arbitrary time blocks, due to improved fits to length composition data and improved model stability. 4) Size composition data from China longline (CNLL) and Vanuatu longline (VULL) were included and fitted in this assessment. However, selectivity was only estimated for one CNLL fleet (CNLL Area 3 and 5), while CNLL Area 2 and 4 and VULL selectivities were mirrored to Taiwan longline (TWLL) selectivity. As a model sensitivity, the 2023 assessment model was updated with 2026 data (to the extent possible) to illustrate the impact of these structural changes (Table ES1).

## Catches

During the modeling period (1994-2024), the total reported catch of north Pacific albacore reached a peak of about 119,000 t in 1999 and then declined since the early 2000s. Catches since 2021 have been about 45,000 t, although catches in 2020 were roughly 75,000t (Fig. ES1). Surface gears (e.g., troll, pole-and-line), which primarily harvest juvenile albacore, have typically accounted for the majority of the albacore catch (Fig. ES2).

## Data and Assessment

All north Pacific albacore catch and size composition data from ISC member (Canada, China, Chinese-Taipei, Japan, Korea, Mexico, and the USA) and non-member countries (e.g., Vanuatu, Kiribati) were compiled for the assessment. The fleet structure was similar to that of the 2020 assessment, which differs from the fleet structure in the 2023 assessment. Specifically, the 2023 assessment had JPLL fleets operating in Areas 1 and 3 (A13) during Quarter 1 (Q1) separated into juvenile and adult fleets. The 2026 assessment reverts to the 2020 fleet structure with just one fleet for JPLL A13 Q1. The fleet structure was revisited during the development process, as the fits to the length composition data were not notably improved when juveniles and adults were modeled separately. Four relative abundance indices (standardized CPUE) were provided by Japan, the USA, and Chinese-Taipei. Based on a thorough review of all fishery data and preliminary model runs, the ALBWG fitted the base case model to one abundance index: the standardized CPUE of the JPLL fleet operating in Area 2 during Quarter 2 (F10 index; 1996 – 2024). This index was chosen because it represented the best information on trends for adult age-classes of female albacore, had good contrast, and age-structured production model (ASPM) analyses indicated the index was informative on both population trends and scale. Previous assessments have used an index from the JPLL fleet in the same area but from Quarter 1, which is the primary albacore-targeting season. However, a re-examination of the data indicated that trends in the adult age-classes of female albacore were likely better represented by the CPUE in Quarter 2, which is also the primary spawning season.

The north Pacific albacore tuna stock was assessed using a length-based, age-, and sex-structured Stock Synthesis (SS; Version 3.30.24) model over the 1994-2024 period. Biological parameters like growth and natural mortality (M), were the same as for the 2017, 2020, and 2023 assessments. Sex-specific growth curves were used because of sexually dimorphic growth, with adult males attaining a larger size-at-age than females after maturity. Sex-specific M-at-age vectors were developed from a meta-analysis, with a sex-combined M that scaled with size for ages 0-2, and sex-specific M fixed at 0.48 and 0.39 $y^{-1}$ for age-3+ females and males, respectively. The steepness of the Beverton-Holt stock-recruitment relationship was assumed to be 0.9, based on two prior analyses. The base case model was fitted to the F10 index and all representative size composition data in a likelihood-based statistical framework.

All but one fleet (USA longline in Areas 2 and 4) were assumed to have dome-shaped length selectivity patterns. Some fleets had high year-to-year variability in the size composition data. For these fleets, age-based selectivity was estimated in addition to length-based selectivity. The goal was to account for age-based changes in juvenile albacore availability and movement. Time-varying age-based selectivities were estimated for four surface fleets (JPPL and EPO surface) in order to further improve fits to the size composition data. The base model converged on a maximum likelihood estimate with a positive, definite Hessian matrix and had good ASPM diagnostics.

Maximum likelihood estimates of model parameters, derived outputs, and their variances were used to characterize stock status. Several sensitivity analyses were conducted to evaluate changes in model performance or the range of uncertainty resulting from changes in model parameters, including growth, natural mortality, stock-recruitment steepness, selectivity patterns, and data weighting.

An ASPM diagnostic analysis showed that the estimated catch-at-age and fixed productivity parameters (growth, mortality and stock-recruitment relationships with and without annual recruitment deviates) were able to explain trends in the primary index. Based on these findings, the ALBWG concluded that the base case model was able to estimate the stock production function and the effect of fishing on the abundance of the north Pacific albacore stock. Similar to the 2020 and 2023 assessments, the link between catch-at-age and the primary index adds confidence to the data used and the results of the assessment. Due to the moderate exploitation levels relative to the productivity, the production function was weakly informative about north Pacific albacore stock size. It is important to note that the primary aim of estimating the female SSB in this assessment was to determine if the estimated SSB was lower than the adopted limit and threshold reference points. Since the lower bound is better defined, it adds confidence to the ALBWG's evaluation of stock condition relative to these reference points.

## Conservation and Management

The WCPFC and IATTC are the tuna RFMOs that manage the north Pacific albacore stock in the WCPO and EPO, respectively, and have adopted similar harvest strategies and biological reference points for this stock (WCPFC NC Harvest Strategy 2023-01; IATTC Resolution C-23-02). These harvest strategies include target, threshold, and limit reference points. The target reference points are F45%SPR, which is the fishing intensity that results in the stock producing a SPR of approximately 45%. The threshold and limit reference points are $30\%SSB_{current,F=0}$ and $14\%SSB_{current,F=0}$, respectively, which are 30% and 14% of the current, dynamic SSB under zero fishing, and hence fluctuates with changes in recruitment. Importantly, three of the management objectives in the harvest strategies are to: 1) maintain SSB above the limit reference point, with a probability of at least 80% over the next 10 years; 2) maintain depletion of total biomass around historical (2006 – 2015) average depletion over the next 10 years; and 3) maintain fishing intensity at or below the target reference point with a probability of at least 50% over the next 10 years. In addition, both RFMOs have current management measures (WCPFC CMM 2019-03; IATTC Resolution C-05-02) that maintain albacore fishing effort at or below the average effort levels during 2002 – 2004.

## Stock Status

Estimated summary biomass (males and females at age-1+) declined at the beginning of the time series until 2004 (Fig. ES3). Subsequently, the summary biomass fluctuated without a trend until 2018, after which the biomass increased to values higher than those at the beginning of the model time period. It should be noted that the high summary biomass estimates since 2018 also had increasing uncertainty (Fig. ES3). These high summary biomass estimates were due to historically high recruitment estimates in 2017 (~297 million fish; 95% CI: 215– 381million fish), 2019 (~292 million fish; 95% CI: 187 to 396 million fish), and 2022 (~314 million fish; 95% CI: 93-536 million fish) (Fig. ES3). However, it should be noted that the recruitment estimates in the last 5 years (2020-2024) were highly uncertain and should be treated with caution. Estimated female SSB exhibited a similar population trend to the summary biomass, albeit with a lag of several years, and showed an initial decline until 2007 followed by fluctuations without a clear trend through 2020 (Fig. ES3).

The average fishing intensity during 2021 – 2023 was estimated to be $F66_{\%SPR}$ (95% CI: $F74_{\%SPR}$ – $F57_{\%SPR}$), which was relatively moderate and resulted in a population with an SPR of approximately 66%. Instantaneous fishing mortality at age (F-at-age) was similar in both sexes through age-5, peaking at age-4 and declining to a low at age-6, after which males experienced higher F-at-age than females up to age 14 (Fig. ES4). Juvenile albacore aged 2 to 4 years comprised approximately 76% of the annual catch-at-age in numbers between 1994 and 2024 (Fig. ES5) due to the larger fishery impact of surface fisheries (primarily troll, pole-and-line), which remove juvenile fish, relative to longline fisheries, which primarily remove adult fish (Fig. ES6).

Stock status is depicted in relation to the target ($F45_{\%SPR}$), threshold ($30\%SSB_{current,F=0}$), and limit ($14\%SSB_{current,F=0}$) reference points (Fig. ES7; Table ES1). The estimated female SSB has never fallen below the threshold and limit reference points since 1994, albeit with large uncertainty in the terminal year (2024) estimates. The historical fishing intensity was estimated to have exceeded the target reference point for most years between 1997-2018. However, the estimated

fishing intensity has been declining since 2019 and has been below the target reference point for the last six years. Even when alternative hypotheses about key model uncertainties such as growth were evaluated, the point estimate of female SSB in 2024 (SSB2024) did not fall below the threshold and limit reference points (Fig. ES7). Estimated average fishing intensity during 2021-2023 (F2021-2023) did not exceed the target reference point under the alternative hypotheses. (Fig. ES7; Table ES1).
Average fishing intensity from 2021-2023 also did not exceed the average fishing intensity during 2002-2004 (Table ES1).

The SSB2024 was estimated to be approximately 60% (95% CI: 38 – 83%) of $SSB_{current,F=0}$ and 2.01 (95% CI: 1.26 – 2.76) times greater than the estimated threshold reference point (Table ES1). The estimated current fishing intensity (F2021-2023) was estimated to be $F66_{\%SPR}$ (95% CI: $F74_{\%SPR}$ – $F57_{\%SPR}$) and was lower than both the $F45_{\%SPR}$ target reference point and the average fishing intensity during 2002 – 2004 (Table ES1).
Based on these findings, the following information on the status of the north Pacific albacore stock is provided:

1. The stock is virtually certain (>99% probability) not to be overfished relative to the threshold (30%SSBcurrent,F=0) and limit (14%SSBcurrent,F=0) reference points adopted by the WCPFC and IATTC, and
2. The stock is virtually certain (>99% probability) to not be experiencing overfishing relative to the target reference point (F45%SPR).

**Future Projections**

A new version of the SSfuture C++software package (ssfcpp version 2.0.4) was developed to perform future projections for this assessment. Two 10-yr projection scenarios, constant F2021-2023 and randomly resampled F2005-2019 scenarios, were used to evaluate the impacts of fishing on the management objectives of IATTC and WCPFC. Each projection scenario consisted of 160,000 (400 x 400) runs, starting in 2025 and continuing for 10 years through 2034. For each scenario, 400 initial populations, together with their stock-recruitment relationships, were simulated by sampling from the estimated N-at-age distributions in 2021. Each initial population was in turn projected using 400 runs with an F-at-age and random recruitment. Most of the uncertainties from the base case model, except for estimation uncertainties of the selectivities and recruitment deviates, were incorporated into the projections. The ALBWG considered these projections to be an improvement over projections from previous assessments but more improvements will still be needed in the future. Depending on the scenario, the F-at-age used was either based on the average F-at-age during 2021 – 2023, or randomly resampled from 2005 – 2019. Both projection scenarios showed similar trends. The constant fishing intensity scenario showed that the current fishing intensity (F2021-2023) is expected to result in female SSB increasing to 109,384 t (95% CI: 82,915– 136,573 t) by 2034. Over the next 10 years, there was: 1) a 100.0% probability of the female SSB remaining above the $14\%SSB_{current,F=0}$ LRP for all 10 years; 2) a 86.5% probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 95.3% probability of the fishing intensity remaining at or below the F45%SPR TRP for any year (Fig. ES9). Similarly, the randomly resampled fishing intensity scenario showed that if future fishing intensity is similar to the 2005 – 2019 period, it is expected to result in female SSB increasing to 67,340 t (95% CI: 47,082 – 87,597 t) by 2034. Over the next 10 years, there was: 1) a 99.1 % probability of the female SSB remaining above the 14%$SSB_{current,F=0}$ LRP for all 10 years; 2) a 79.9 % probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 48.8% probability of the fishing intensity remaining at or below the F45%SPR TRP for any year (Fig. ES10).

**Conservation Information**

Two harvest scenarios were projected to evaluate impacts on the management objectives of IATTC and WCPFC for this stock: 1) maintain SSB above the limit reference point, with a probability of at least 80% over the next 10 years; 2) maintain depletion of total biomass around historical (2006 – 2015) average depletion over the next 10 years; and 3) maintain fishing intensity at or below the target reference point with a probability of at least 50% over the next 10 years (WCPFC HS 2023-01; IATTC Resolution C-23-02). As a larger cohort is estimated in the latest period of the assessment, all projections show a steep increase of SSB in the first year.

The constant fishing intensity scenario showed that the current fishing intensity (F2021-2023) is expected to result in female SSB increasing to 109,384 t (95% CI: 82,915 – 136,573 t) and a SSB/$SSB_{current,F=0}$ ratio of 0.83 by 2034. Over the next 10 years, there was: 1) a 100.0% probability of the female SSB remaining above the 14%$SSB_{current,F=0}$ LRP for all 10 years; 2) a 86.5% probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 95.3% probability of the fishing intensity remaining at or below the $F45_{\%SPR}$ TRP for any year. The randomly resampled fishing intensity scenario showed that if future fishing intensity is similar to the 2005 – 2019 period, it is expected to result in female SSB increasing to 67,340 t (95% CI: 47,082 – 87,597 t) and a SSB/$SSB_{current,F=0}$ ratio of 0.52 by 2034. Over the next 10 years, there was: 1) a 99.1 % probability of the female SSB remaining above the 14%$SSB_{current,F=0}$ LRP for all 10 years; 2) a 79.9 % probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 48.8% probability of the fishing intensity remaining at or below the $F45_{\%SPR}$ TRP for any year.

Based on these findings, the following conservation information is provided:

1. If fishing intensity over the next 10 years is maintained at the current fishing intensity (F2021-2023), then female SSB is expected to increase to around 83% of $SSB_{current,F=0}$ (109,384 t) by 2034, with a 100.0% probability that female SSB will remain above the 14%$SSB_{current,F=0}$ LRP for all 10 years and the harvest strategy management objectives of the IATTC and WCPFC (IATTC Resolution C-23-02; WCPFC Harvest Strategy 2023-01) will likely be met; and

2. If fishing intensity over the next 10 years is similar to the 2005 – 2019 period, then female SSB is expected to decrease to around 52% of $SSB_{current,F=0}$ (67,340 t), with a 99.1 % probability that female SSB will remain above the 14%$SSB_{current,F=0}$ LRP for all 10 years and the harvest strategy management objectives of the IATTC and WCPFC (IATTC Resolution C-23-02; WCPFC Harvest Strategy 2023-01) will likely be met.

**Key Uncertainties**

The ALBWG notes that the uncertainty in growth and natural mortality and the simplified treatment of the spatial structure of north Pacific albacore population dynamics are important sources of uncertainty in the assessment.

**Exceptional Circumstances**

The adopted harvest strategies of the WCPFC and IATTC for North Pacific albacore tuna include provisions for the identification and evaluation of exceptional circumstances that may warrant suspension or modification of the current strategies. Consistent with this requirement, the ALBWG evaluated the adopted criteria for identifying exceptional circumstances for North Pacific albacore tuna, including indicators related to stock and fleet dynamics, application of the stock assessment, and implementation of management measures. Based on the information available and the evaluation criteria, the ALBWG found no evidence to indicate that exceptional circumstances were present with respect to the conservation and management of the stock.

**Table ES1**: Estimates of maximum sustainable yield (MSY), female spawning stock biomass (SSB), fishing intensity (F), and reference point ratios for north Pacific albacore tuna for: 1) the base case model; 2) one important sensitivity model due to uncertainty in growth parameters; 3) a model representing an update of the 2023 base case model to 2026 data; and 4) a model representing uncertainty in the specification of initial fishing mortality.$SSB_0$, $SSB_{current,F=0}$, and $SSB_{MSY}$ are the expected female SSB of a population in the equilibrium, unfished state; in the current, dynamic, unfished state; and at MSY, respectively. The Fs in this table are indicators of fishing intensity based on spawning potential ratio (SPR) and calculated as %SPR. SPR is the ratio of the equilibrium SSB per recruit that would result from the estimated F-at-age relative to that of an unfished population. Depletion is calculated as the proportion of the age-1+ biomass during the specified period relative to an unfished age-1+ equilibrium biomass. The model representing an update of the 2023 base case model is similar to but not identical to the 2026 base case model due to changes in data preparation and model structure. †A value of >1 for the depletion ratio indicates higher age-1+ biomass in 2024 relative to the 2006–2015 period. §Higher %SPR values indicate lower fishing intensity levels. ¶Values of >1 for ratios of $F_{\%SPR}$ to $F_{\%SPR}$-based reference points indicate fishing intensity levels lower than the reference points.

| Quantity | Base Case | Growth CVold=0.06 | Update of 2023 base case model to 2026 data* | Initial Conditions initF F20 F24 |
|---|---|---|---|---|
| MSY (t) | 106,578 | 86,675 | 113,793 | 100,322 |
| $SSB_{MSY}$ (t) | 19,360 | 15,878 | 20,524 | 18,316 |
| $SSB_0$ (t) | 139,466 | 113,685 | 147,874 | 131,221 |
| $SSB_{2024}$ (t) | 84,209 | 49,547 | 96,362 | 73,236 |
| $SSB_{current, F=0}$ (2024 estimate) | 139,777 | 107,072 | 151,193 | 129,224 |
| $SSB_{2024}/SSB_{current, F=0}$ | 0.60 | 0.46 | 0.64 | 0.57 |
| $SSB_{2024}/30\%SSB_{current, F=0}$ | 2.01 | 1.54 | 2.12 | 1.89 |
| $SSB_{2024}/14\%SSB_{current, F=0}$ | 4.30 | 3.31 | 4.55 | 4.05 |
| † $Depletion_{2024}/Depletion_{2006-2015}$ | 1.45 | 1.40 | 1.61 | 1.45 |
| § $F_{\%SPR, 2021-2023}$ (%SPR) | 65.6 | 51.9 | 68.0 | 62.2 |
| § $F_{\%SPR, 2013-2023}$ (%SPR) | 50.3 | 36.7 | 53.6 | 46.6 |
| ¶ $F_{\%SPR, 2021-2023}/F_{\%SPR, MSY}$ | 4.03 | 3.17 | 4.18 | 3.80 |
| ¶ $F_{\%SPR, 2013-2023}/F45_{\%SPR}$ | 1.12 | 0.82 | 1.19 | 1.04 |
| ¶ $F_{\%SPR, 2021-2023}/F45_{\%SPR}$ | 1.46 | 1.15 | 1.51 | 1.38 |
| ¶ $F_{\%SPR, 2021-2023}/F_{\%SPR, 2002-2004}$ | 1.87 | 2.13 | 1.78 | 1.95 |

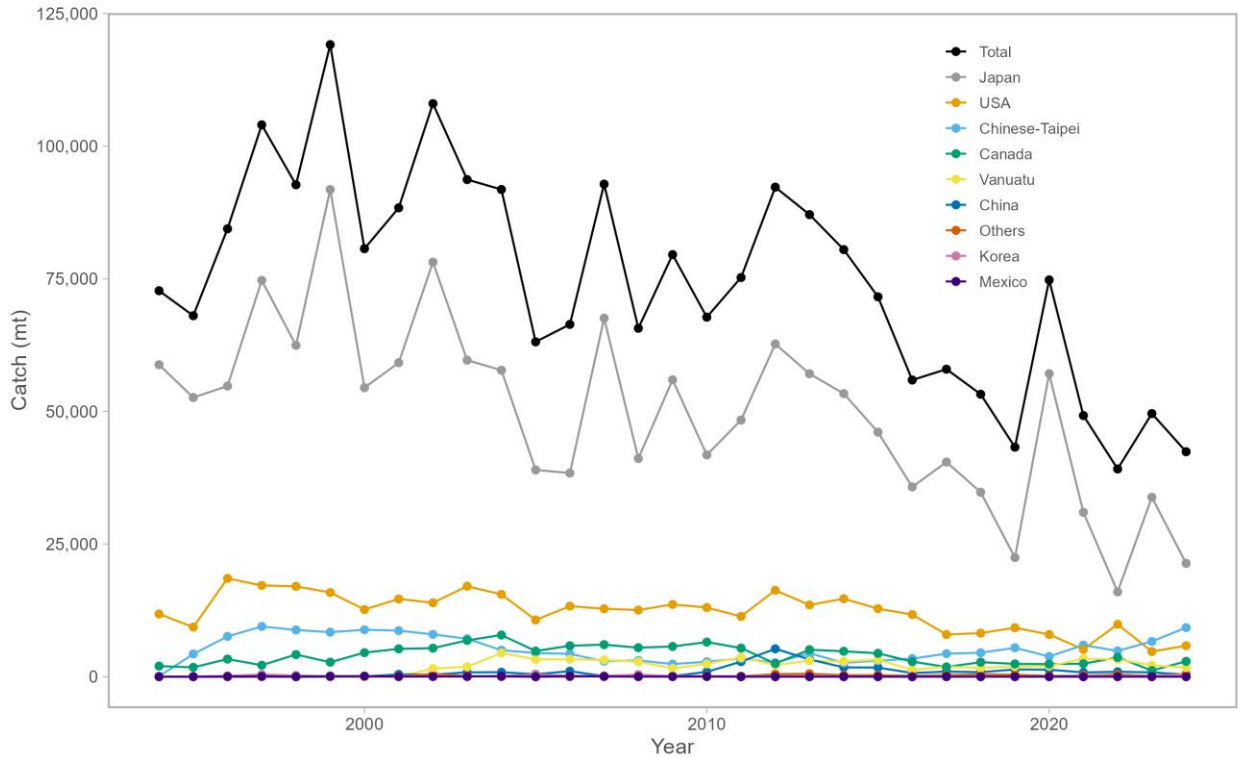


**Figure ES1**: Estimated total annual catch of north Pacific albacore (*Thunnus alalunga*) by all countries harvesting the stock, 1994-2024. Catches in the "Others" categories includes small amount of catch by other countries such as Kiribati, Belize, Panama, and Marshall Islands.

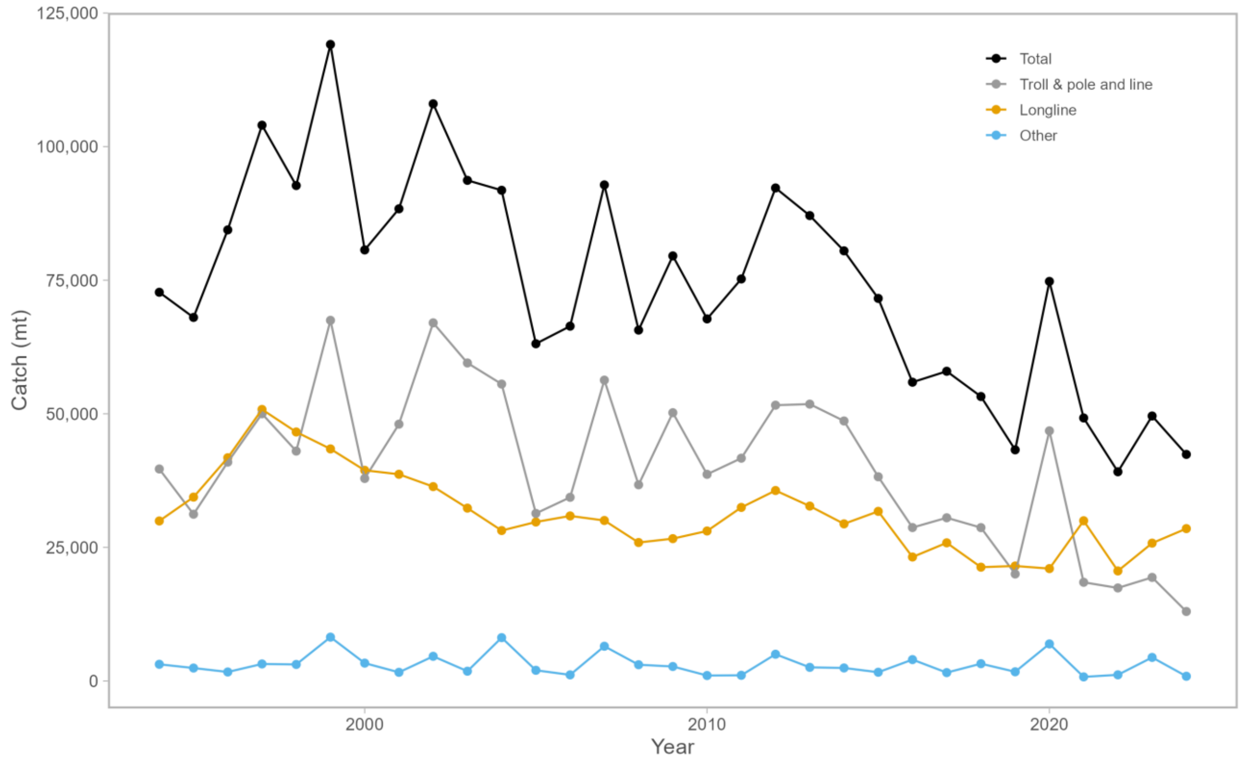


**Figure ES2**: Estimated catches of north Pacific albacore by major gear types, 1994-2024. The Other gear category includes catches with purse seine, gillnet, hand lines, and harpoons.

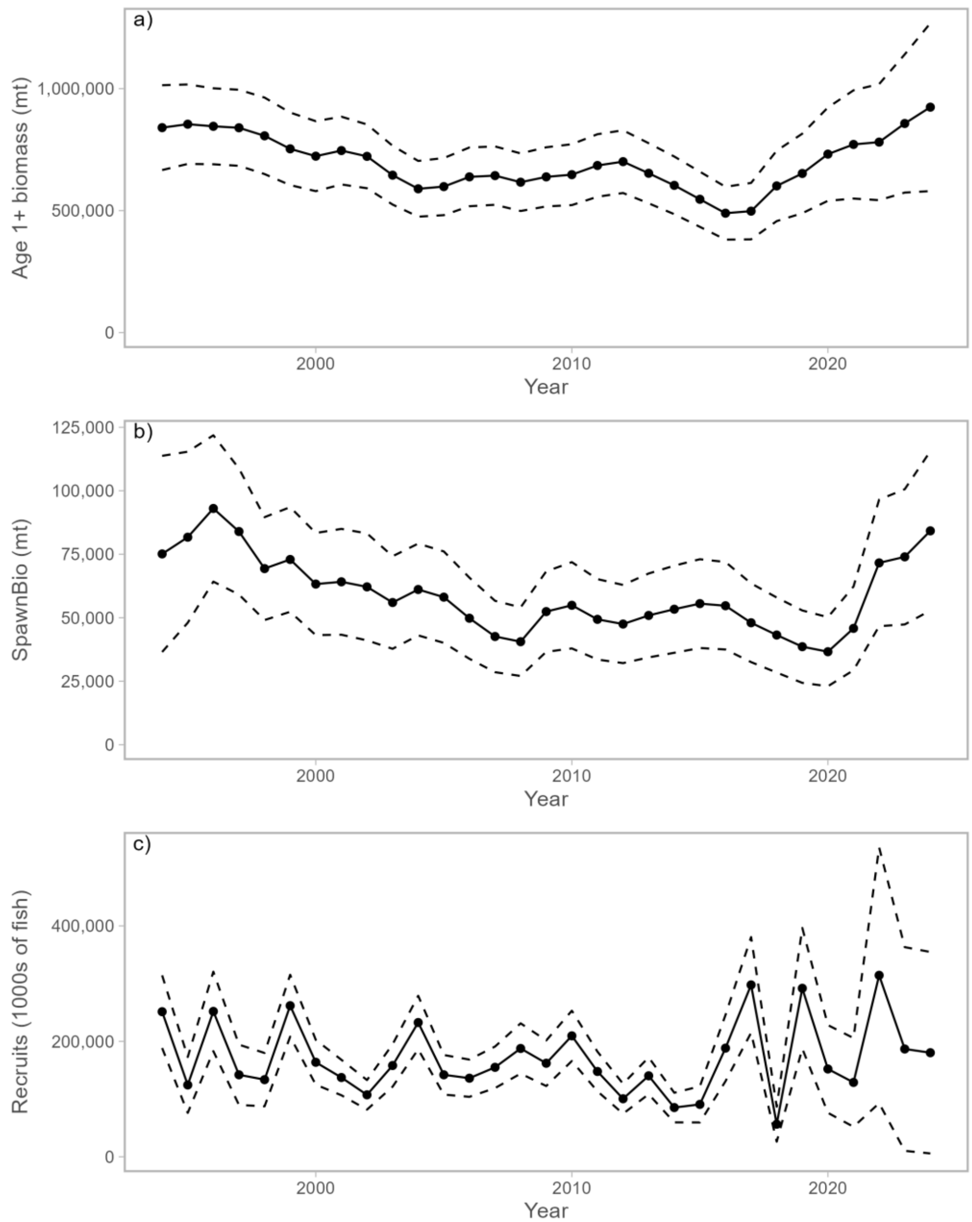


**Figure ES3**: Maximum likelihood estimates of (a) age-1+ biomass, (b) female spawning biomass (SSB), and (c) age-0 recruitment of north Pacific albacore tuna (*Thunnus alalunga*). Dashed lines indicate 95% confidence intervals.

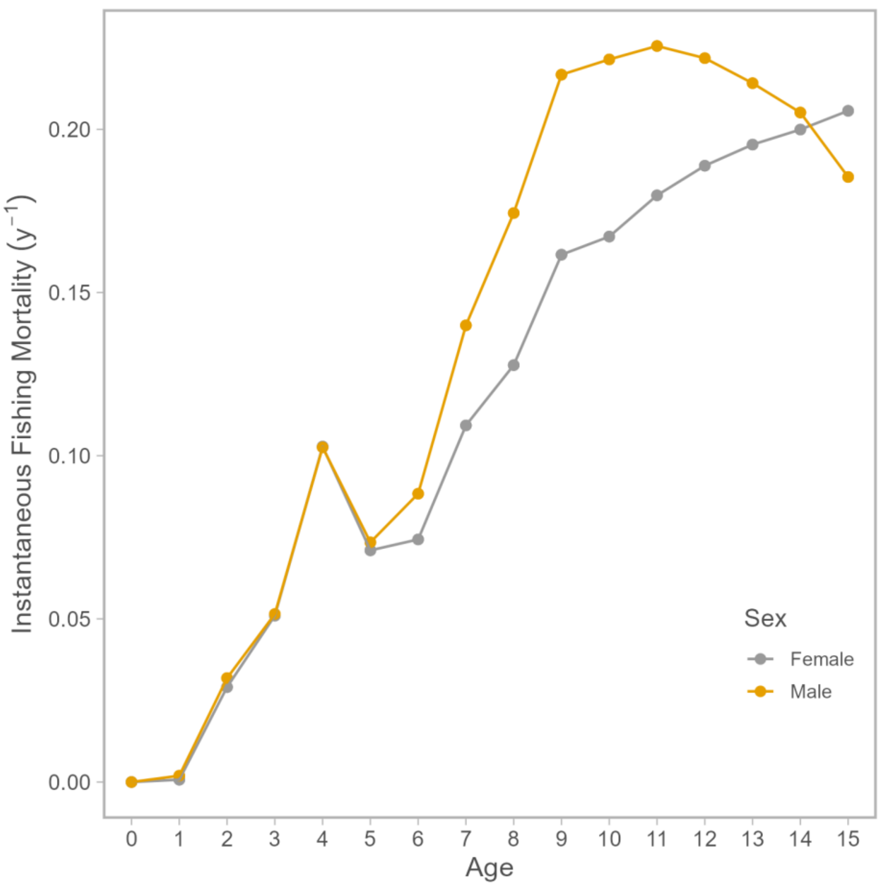


**Figure ES4**: Estimated sex-specific instantaneous fishing mortality at age (F-at-age) for the 2026 base case model, averaged across 2021-2023.

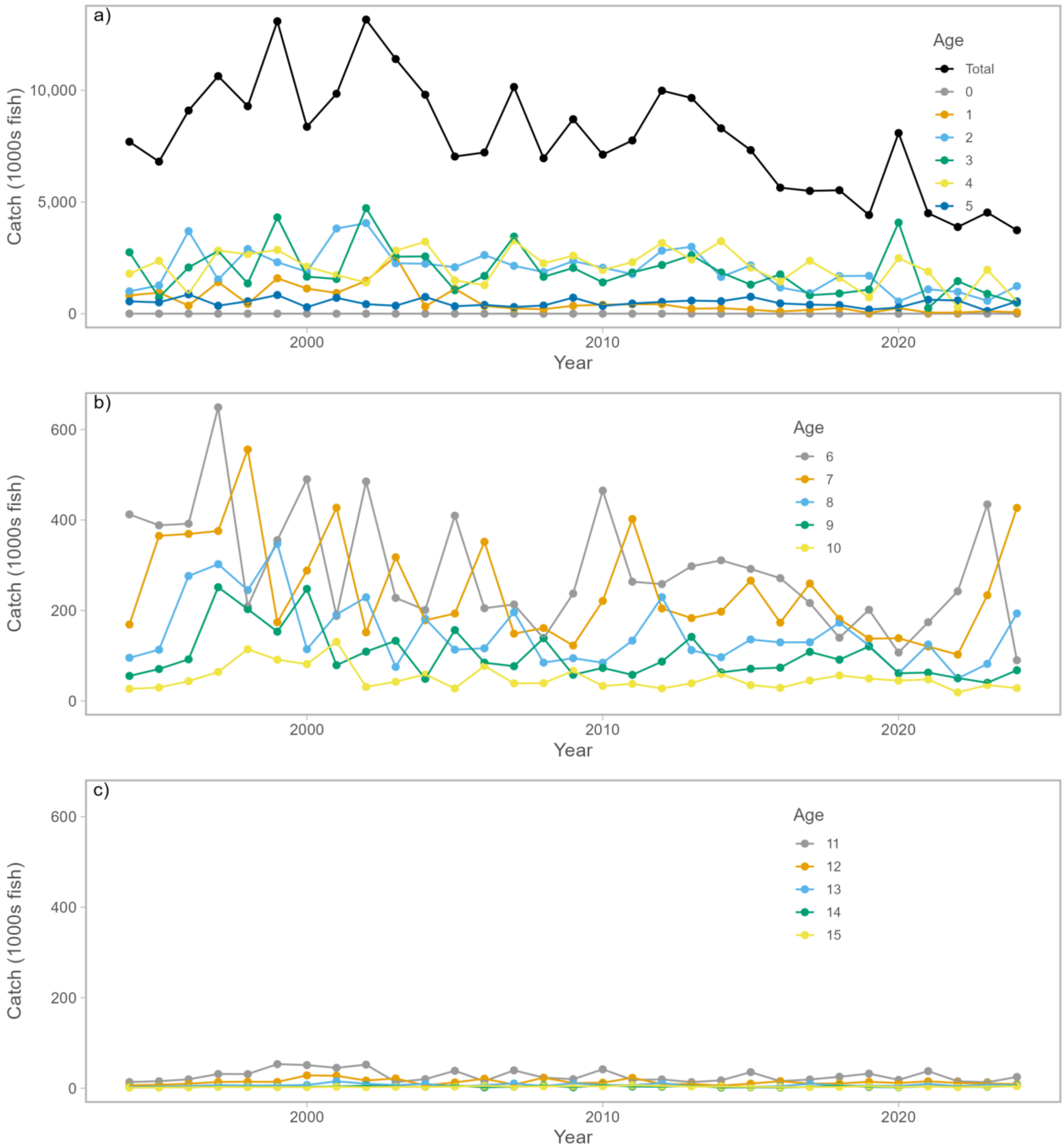


**Figure ES5**: Historical catch at age of north Pacific albacore estimated by the 2026 base case model. Panels are arranged for the total catch and ages 0-5 (top), 6-10 (middle), and 11-15 (bottom). Note the difference in y-axis scale between the top panel and middle and bottom panels.

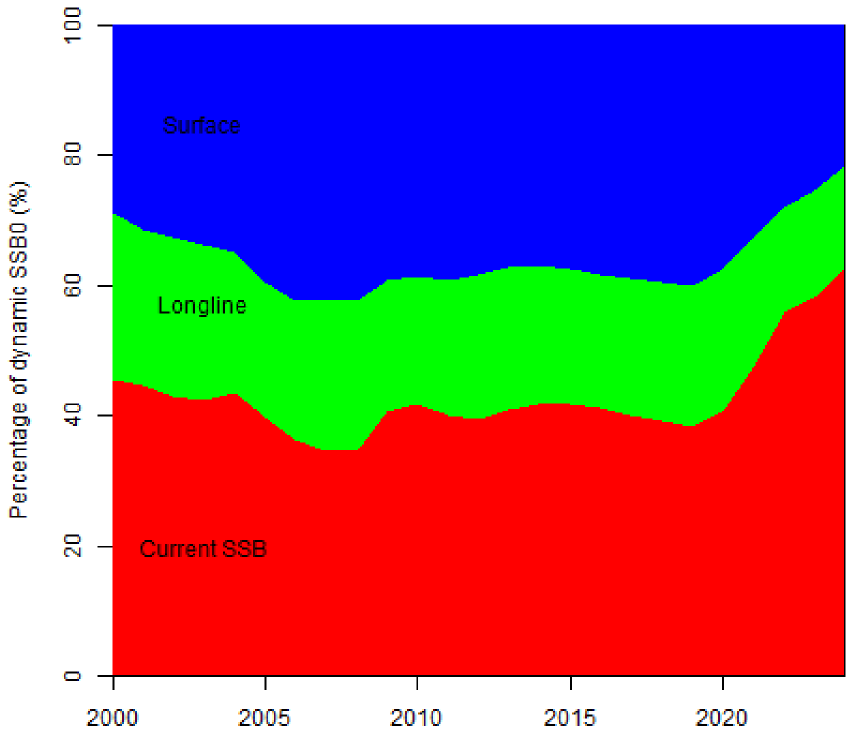


**Figure ES6**: Fishery impact analysis on north Pacific albacore showing female spawning biomass (SSB; red) estimated by the 2026 base case model as a percentage of dynamic, unfished female SSB ($SSB_{current,F=0}$). Colored areas show the relative proportion of fishing impact attributed to longline (green) and surface (blue) fisheries (primarily troll and pole-and-line gear, but including all other gears except longline).

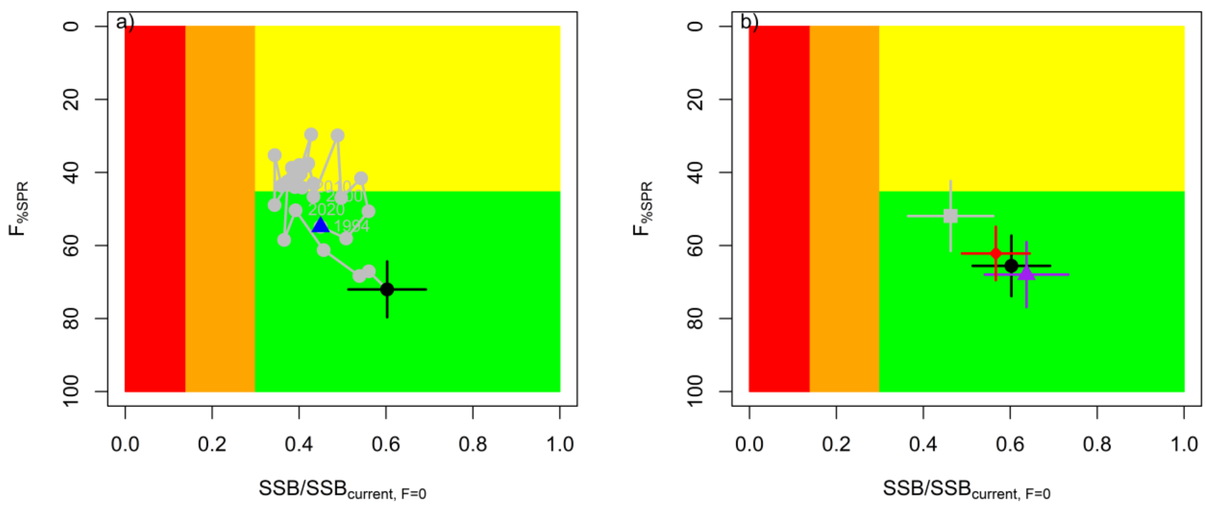


**Figure ES7**: (a) Stock status phase plot showing the status of the north Pacific albacore (*Thunnus alalunga*) stock relative to the biomass-based threshold (30%$SSB_{current,F=0}$) and limit (14%$SSB_{current,F=0}$) reference points, and fishing intensity-based target reference point (F45%SPR) over the modeling period (1994 – 2024). Blue triangle indicates the start year (1994) and black circle with 95% confidence intervals indicates the terminal year (2024). (B) Stock status plot showing current stock status and 95% confidence intervals of the base case model (black circle), a sensitivity run an important sensitivity run of CV = 0.06 for Linf in the growth model (gray), an important sensitivity run with two initial fishing mortality parameters (red), and a model representing an update of the 2023 base case model to 2026 data (purple). Red zones in both panels indicate female SSBs falling below the limit reference point while the orange zones indicate female SSBs between the threshold and limit reference points. Green zones indicate female SSBs above the threshold reference point and fishing intensity levels below the target reference point. Yellow areas indicate female SSBs above the threshold reference point and fishing intensity levels above the target reference point. The Fs in this figure are indicators of fishing intensity based on spawning potential ratio (SPR) and calculated as %SPR. SPR is the ratio of the equilibrium SSB per recruit that would result from the estimated F-at-age relative to that of an unfished population. A higher %SPR indicates lower fishing intensity. Current fishing intensity values and $SSB/SSB_{current,F=0}$ ratios in (B) were calculated as the average during 2021-2023 (F%SPR, 2021-2023) and 2024 ($SSB2024/SSB_{current,\ F=0}$), respectively. The model representing an update of the 2023 base case model is similar to but not identical to the 2023 base case model due to changes in data preparation and model structure.

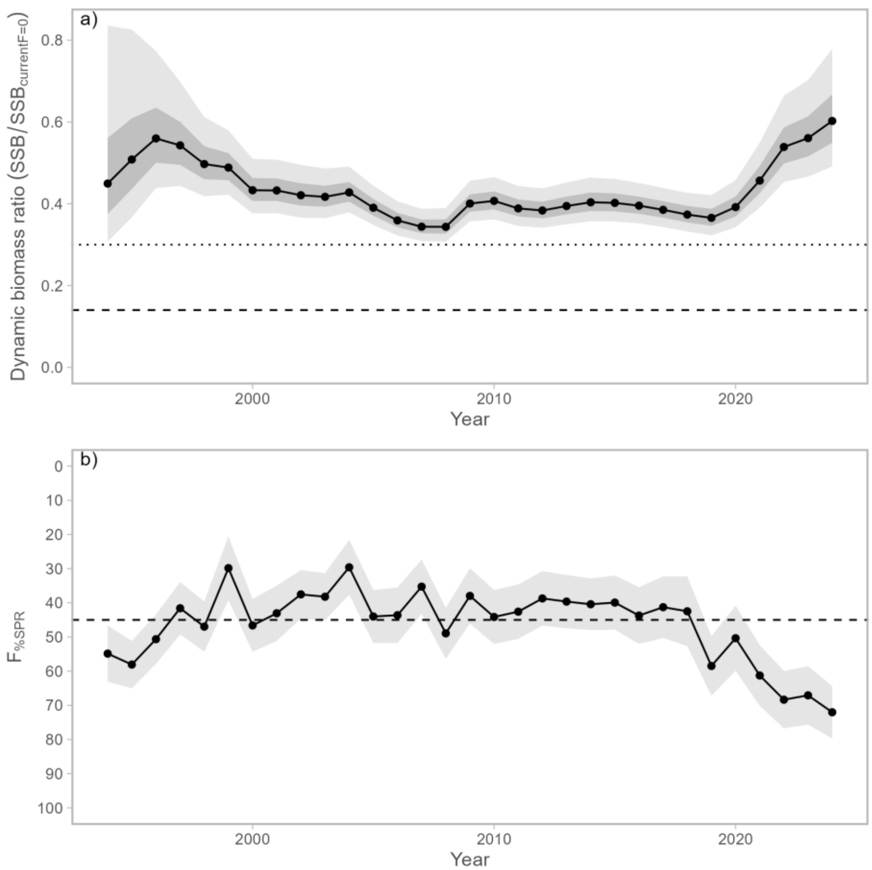


**Figure ES8**: (A) Estimated dynamic biomass ratio (SSB/SSB$_{current,\ F=0}$) of north Pacific albacore relative to biomass-based threshold (30%SSB$_{current,\ F=0}$; dotted line) and limit (14%SSB$_{current,\ F=0}$; dashed line) reference points over the modeling period (1994 – 2024). 95% confidence intervals are indicated by the lighter gray bands and 60% confidence intervals are indicated by the darker gray bands. (B) Estimated fishing intensity relative to the fishing intensity-based target reference point (F45%SPR) over the modeling period (1994 – 2024). The gray area indicates the 95% confidence intervals. The limit reference point is considered to be breached if the lower bound of the 60% confidence intervals overlaps the limit reference point.

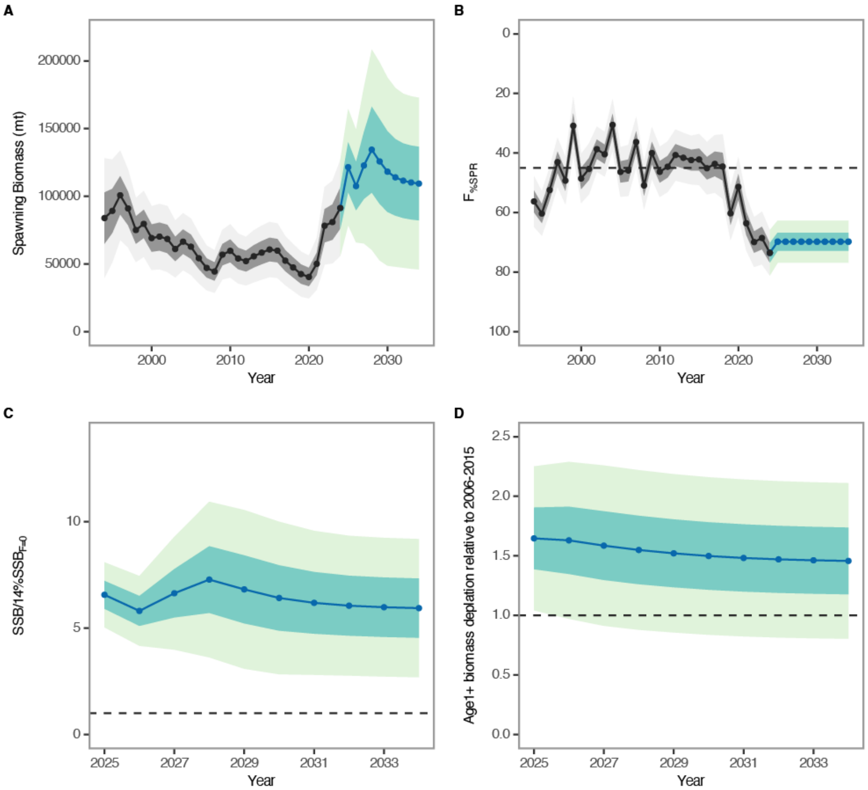


**Figure ES9**: Future projection results under a constant fishing intensity (F2021-2023) harvest scenario. Solid lines indicate mean values, uncertainty ranges indicate 60% and 95% confidence intervals, and the dashed line is the reference point, respectively. (A) Annual changes in spawning biomass; (B) Interannual changes in fishing mortality (F%SPR); (C) Projected ratios to the limit reference point thresholds; and (D) Projected ratios to management targets for the total biomass.

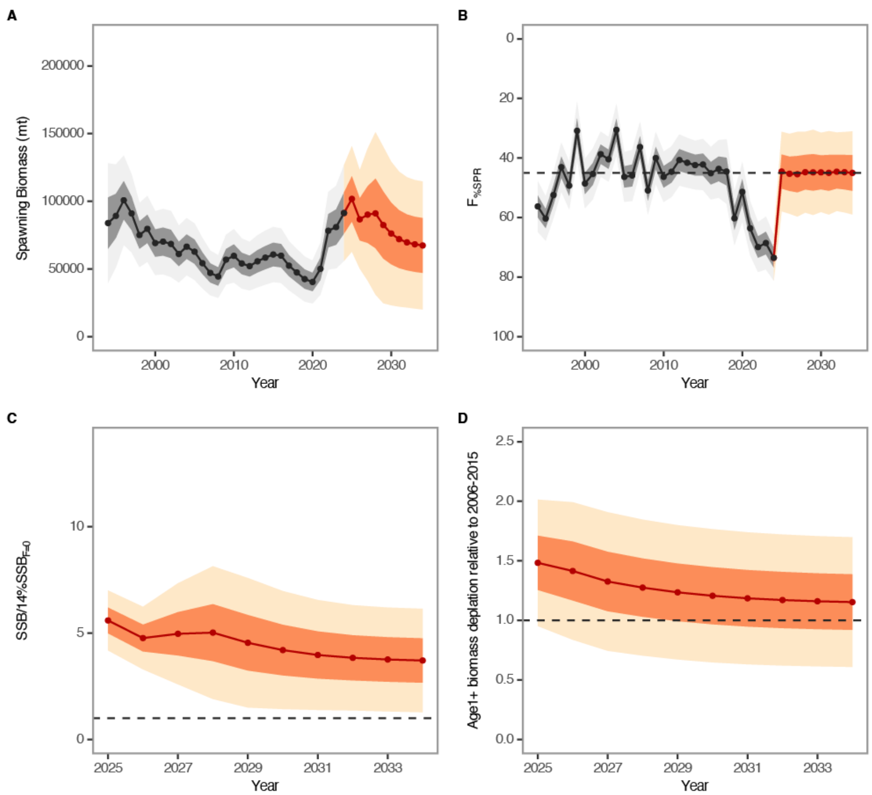


**Figure ES10**: Future projection results under a randomly F (2005-2019) scenario. Solid lines indicate mean values, and uncertainty ranges indicate 60% and 95% confidence intervals, and the dashed line is the reference point, respectively. (A) Annual changes in spawning biomass; (B) Interannual changes in fishing mortality (F%SPR); (C) Projected ratios to the limit reference point thresholds; and (D) Projected ratios to management targets for the total biomass.

# 1 INTRODUCTION

The ALBWG of the ISC is tasked with conducting regular stock assessments of north Pacific albacore tuna (*Thunnus alalunga*) to estimate population parameters, summarize stock status, and develop scientific advice on conservation and management needs for fisheries managers. The origins of the ALBWG date to 2005 when the *North Pacific Albacore Workshop*, which was established in 1974 to promote cooperative research and stock assessment analyses on north Pacific albacore, was integrated into the ISC. The ALBWG includes members from coastal states and fishing entities of the region (Canada, China, Chinese-Taipei, Japan, Korea, Mexico, USA) and members from relevant regional fishery and marine science organizations (e.g., IATTC, SPC).

The WCPFC and IATTC are the tuna RFMOs that manage the north Pacific albacore stock in the WCPO and EPO, respectively. Both RFMOs have adopted similar harvest strategies and biological reference points for this stock (currently WCPFC NC Harvest Strategy 2023-01; IATTC Resolution C-23-02). These harvest strategies include target, threshold, and limit reference points. The target reference points are $F45_{\%SPR}$, which is the fishing intensity that results in the stock producing a SPR of approximately 45%. The threshold and limit reference points are $30\%SSB_{current,F=0}$ and $14\%SSB_{current,F=0}$, respectively, which are 30% and 14% of the current, dynamic SSB under zero fishing, and hence fluctuates with changes in recruitment. Importantly, the management objectives in the harvest strategies are to: 1) maintain SSB above the limit reference point, with a probability of at least 80% over the next 10 years; 2) maintain depletion of total biomass around historical (2006–2015) average depletion over the next 10 years; and 3) maintain fishing intensity at or below the target reference point with a probability of at least 50% over the next 10 years. In addition, both RFMOs have current management measures (WCPFC CMM 2019-03; IATTC Resolution C-05-02) that maintain albacore fishing effort at or below the average effort levels during 2002–2004.

The previous stock assessment in 2023 (ALBWG 2023a) used an integrated, length-based, and age- and sex-structured forward-simulating statistical stock assessment model in the Stock Synthesis (SS) modeling framework (Methot and Wetzel 2013) to assess stock status. Model diagnostics indicated that the model was able to estimate the stock production function and the effect of fishing on the abundance of the north Pacific albacore stock. The link between catch-at-age and the abundance index added confidence to the data used, the results of the assessments, and the estimated population scale. Female SSB in the terminal year of the assessment (i.e., 2021) was estimated to be 54% of unfished SSB and fishing intensity on the stock was relatively low (i.e., $F_{2018\text{-}2020} = F59_{\%SPR}$). In 2023, the ALBWG concluded that the north Pacific albacore stock was not likely in an overfished condition relative to the $30\%SSB_{current,F=0}$ threshold and $14\%SSB_{current,F=0}$ limit reference adopted by the WCPFC and IATTC. The ALBWG also concluded the stock was likely not experiencing overfishing relative to the adopted target reference point of $F45_{\%SPR}$.

The adoption of the abovementioned biological reference points in 2022 re-emphasized the importance of estimating population scale from the assessment models. Therefore, during the 2026 assessment, the ALBWG focused on maintaining the ability of the assessment model to estimate the stock production function and the effect of fishing on the abundance of the north Pacific albacore stock. The 2023 assessment had a similarly prioritized estimation of population scale. Based on analyses of the data and preliminary models, the ALBWG made four important changes to the base case model in this assessment compared to the previous assessment in 2023 (see Section 2.4). However, these changes were relatively minor compared to those between previous assessments e.g. (ALBWG 2017, 2020). 1) The F10 JPLL index was recalculated with data from 1996-2024 and an expanded area that matched the spatial definitions in the stock assessment rather than that defined in the historical Japanese longline data. 2) Two JPLL fleets for juvenile and adult fleets (i.e., F1 and F2) in the 2023 assessment were combined into one fleet here (F1 in 2026 assessment) and modelled with time-varying age-based selectivity because having two fleets in the 2023 assessment did not improve fits to the size data and did not remove the need for time-varying selectivity. 3) Time-varying age-based selectivity was estimated with two-dimensional autoregressive selectivity patterns rather than assuming arbitrary time blocks, due to improved fits to length composition data and improved model stability. 4) Size composition data from China longline (CNLL) and Vanuatu longline (VULL) were included in the assessment. Selectivity was estimated for data from one CNLL fleet (CNLL Areas 3 and 5), while CNLL Areas 2 and 4 and VULL size composition data were modeled with selectivities mirrored from the Taiwan longline (TWLL) selectivity.

This report presents the results of the 2026 assessment of north Pacific albacore tuna, and provides scientific advice on stock status and conservation information to fisheries managers. The assessment uses updated fishery data through 2024 in a length-based, age- and sex-structured integrated statistical stock assessment model fitted to an abundance index derived from JPLL data that was considered to be representative of adult albacore abundance in the north Pacific Ocean. The biological parameters used in the base case model were identical to the 2023 assessment. This assessment was conducted through a series of in-person and online meetings during 2025 – 2026, and supersedes the 2023 assessment (ALBWG 2023a). The objectives of this assessment are to: 1) understand the population dynamics of the north Pacific albacore tuna stock by estimating population parameters such as time series of recruitment, biomass and fishing intensity; 2) determine stock status by summarizing results relative to the suite of adopted biological reference points; and 3) to provide conservation information for fisheries managers on whether management objectives in the harvest strategies are likely to be met, based on projections using two historical harvest scenarios.

# 2 BACKGROUND

## 2.1 Biology

### 2.1.1 Stock structure

Albacore tuna in the Pacific Ocean consist of the north Pacific stock (focus of this assessment) and the south Pacific stock. The discreteness of these stocks is supported by fishery data. There are lower catch rates in equatorial regions (Suzuki *et al.* 1977), there are no South Pacific Ocean recoveries of fish tagged in the north Pacific Ocean (Ramon and Bailey 1996), albacore larvae are rare in samples from equatorial waters (Ueyanagi 1969), and there is genetic differentiation between north and south Pacific albacore (Takagi *et al.* 2001). In addition, a recent study of single nucleotide polymorphisms of north Pacific albacore from a wide range of locations suggested that the north Pacific albacore stock is best thought of as a single, well-mixed stock with limited amounts of mixture from the south Pacific albacore stock (Vaux *et al.* 2021). Thus, north Pacific albacore is assumed to be a discrete, reproductively isolated stock, with no internal sub-group structure within the stock.

### 2.1.2 Reproduction

Albacore are batch spawners, shedding hydrated oocytes, in separate spawning events, directly into the sea where fertilization occurs. Spawning frequency is estimated to be 1.7 d in the western Pacific Ocean (Chen *et al.* 2010), and batch fecundity ranges between 0.17 and 2.6 million eggs (Ueyanagi 1957; Otsu and Uchida 1959; Chen *et al.* 2010). Female albacore mature at lengths ranging from 83 cm fork length (FL) in the western Pacific Ocean (Chen et al. 2010) to 90 cm FL in the central Pacific Ocean (Ueyanagi 1957), and 93 cm FL in waters north of Hawaii (Otsu and Uchida 1959).

Spawning occurs primarily in tropical and sub-tropical waters between Hawaii (155°W) and the east coast of Taiwan and the Philippines (120°E) and between 10 and 25°N latitudes at depths exceeding 90 m (Ueyanagi 1957, 1969; Otsu and Uchida 1959; Yoshida 1966; Chen *et al.* 2010). Although spawning probably occurs over an extended period from March through September in the western and central Pacific Oceans, recent evidence based on a histological assessments of gonadal status and maturity (Chen *et al.* 2010) shows that spawning peaks in the March-April period in the western Pacific Ocean, which is consistent with evidence from larval sampling surveys in the same region (Nishikawa *et al.* 1985). In contrast, studies of albacore reproductive biology in the central Pacific Ocean have concluded that there was a probable peak spawning period between June and August (Ueyanagi 1957; Otsu and Uchida 1959) but these studies were based on indirect observation methods, were more than 50 years old, and have not been updated using modern histological techniques (e.g. Chen *et al.* 2010).

### 2.1.3 Growth

Growth of albacore tuna is commonly modeled by a von Bertalanffy growth function, with rapid growth in immature fish followed by a slowing of growth rates at maturity and through the adult period. Growth in the first year of life is uncertain since these young fish are rarely captured in any of the active fisheries in the north Pacific Ocean. However, juvenile albacore recruit into intensive surface fisheries in both the eastern and western Pacific Oceans at primarily age-2 and as a result, much better size-at-age and growth information is available. Early growth models combined both sexes because sex-specific fishery data were not collected, although it was known that adult males attained a larger size than females (Otsu and Uchida 1959; Yoshida 1966; Otsu and Sumida 1968). Chen et al. (2012) provided clear evidence of sexually dimorphic growth functions for males and females after they reach sexual maturity and reported that males attained a larger size and older age than females (114 cm FL and 14 years vs. 103.5 cm FL and 10 years, respectively).

A re-examination of the age and growth data compiled by Wells et al. (2013), some of which were used as conditional age-at-length data in the 2011 assessment, showed that for those individuals in which sex was recorded, there was clear evidence of sexually dimorphic growth between males and females (Xu *et al.* 2014). Given the clear evidence of sexual dimorphism in the growth and longevity of north Pacific albacore, the ALBWG used the same sex-specific male and female von Bertalanffy growth functions in this assessment as used in the assessments from 2014 through 2023. These growth parameters were estimated external to the stock assessment model by Xu et al. (2014), who combined the sex-specific datasets compiled by Chen et al. (2012) and Wells et al. (2013). James et al. (2020b) concurred that the current sex-specific growth parameters are the best available scientific information but also suggested that the ALBWG collect sex-specific age-length samples using a coordinated biological sampling plan (James *et al.* 2020a) to improve current growth curves, and examine regional and temporal differences in length-at-age.

### 2.1.4 Movements

North Pacific albacore are highly migratory and these movements are influenced by oceanic conditions (e.g. Polovina *et al.* 2001; Zainuddin *et al.* 2006, 2008). The majority of the migrating population is believed to be composed of juvenile fish (i. e., immature animals that are less than 5 years old and 85 cm FL), which generally inhabit surface waters (0-50 m) in the Pacific Ocean. Some juvenile albacore undertake trans-Pacific movements and display seasonal movements between the eastern or western and central Pacific Ocean (Ichinokawa *et al.* 2008; Childers *et al.* 2011). The trans-Pacific movements track the position of the transition zone chlorophyll front (Polovina *et al.* 2001; Zainuddin *et al.* 2006, 2008) and increase when large meanders in the Kuroshio current occur, increasing albacore prey availability in the transition zone (Kimura *et al.* 1997; Watanabe *et al.* 2004). Westward movements of juveniles tend to be more frequent than eastward movements (Ichinokawa *et al.* 2008), corresponding to the recruitment of juvenile fish into fisheries in the western and eastern Pacific Ocean and are followed by a gradual movement of older juveniles and mature fish to low latitude spawning grounds in the western and central Pacific Ocean. These general patterns may be complicated by seasonal movements of juvenile and adult fish, as well as sex-specific movements of large adult fish, which may be predominately male, to areas south of 20°N. The significance of sex-specific movements on the population dynamics of this stock is uncertain at present.

## 2.2 Fisheries

Albacore tuna is a valuable species with a long history of exploitation in the north Pacific Ocean by numerous nations and with a variety of gears (Clemens 1961). Over the assessment period (1994 – 2024), the total reported catch of north Pacific albacore for all nations combined peaked at a 119,121 t in 1999 and reached lows of 39,153 and 42,402 t in 2022 and 2024, respectively (Fig. 11.1). Average catch over the model time frame (1994-2024) was 74,551 t. Over the last five years (2020-2024), Japanese fisheries accounted for 59.7% of the annual total harvest on average, followed by fisheries from the USA (13.9%), Chinese-Taipei (13%), Canada (5.3%), China (1.7%), Korea (0.5%), and Mexico (0%). During the same five-year period, non-ISC countries, primarily Vanuatu, harvested an average of 5.3% of the total annual catch (Fig. 11.1).

The main gears deployed to harvest albacore in the north Pacific Ocean are longline, and surface gears like troll and pole-and-line (Fig. 11.2). Surface fisheries capture smaller, juvenile fish, and include the Canada and USA troll and pole-and-line fisheries and JPPL fisheries. Over the assessment time frame (1994–2024), surface fisheries have harvested approximately 50.9% of the north Pacific albacore catch. Longline fisheries, which fish deeper in the water column and tend to capture a larger mix of age classes, were responsible for harvesting about 45.2% of the albacore during the same period, with major fleets from Japan, Chinese-Taipei, the USA, and more recently China and Vanuatu. Pole-and-line catches in the 2000s exhibited greater year-to-year variability than other gear types due to target switching between skipjack (*Katsuwonus* *pelamis*) and albacore by some vessels on the fishing grounds off the east coast of Japan (Kiyofuji and Uosaki 2010).

An important fishery in previous assessments was the high seas drift gillnet fishery that began in 1978 and ceased operations in 1993 as a result of United Nations General Assembly Resolution 44/225, which put in place a moratorium on the use of high seas driftnets (Uosaki *et al.* 2011). The high seas drift gillnet fisheries consisted of two main gear types using: 1) large-mesh nets primarily targeting tunas, billfishes, sharks (i.e., tuna gillnet); and 2) small-mesh nets targeting flying squid [i.e. squid gillnet; Ito *et al.* (1993)]. Previous assessments developed base case or sensitivity models with a start year of 1966. However, the ALBWG continued not to do so for this assessment because of previously identified problems with the data from this fishery (ALBWG 2022). Most importantly, the ALBWG found that the records of Japanese drift gillnet catches of north Pacific albacore consisted primarily of landings by large-mesh gillnets but did not include large amounts of removals by the squid gillnets. Estimates of these unaccounted albacore removals by the Japanese squid gillnet fishery approximated 1.4 and 0.9 million fish for 1989 and 1990, respectively (Yatsu *et al.* 1993). The squid gillnet fisheries of Korea and Chinese-Taipei were also substantial and on a similar scale to the Japanese squid gillnet fishery but there have been no estimates of albacore bycatch for these fisheries (Gong *et al.* 1993; Yeh and Tung 1993). The ALBWG therefore recommended that research be performed to develop timeseries of catch and size compositions from these fisheries in part from available observer data (Fitzgerald *et al.* 1993; ALBWG 2022). Given the start year of 1994 and the initial conditions used for this assessment, the problems with the data from the high seas drift gillnet fisheries are not important for this assessment.

## 2.3 Conceptual Model

Based on numerous discussions on the biology and fisheries of north Pacific albacore tuna, the ALBWG developed a conceptual model for the 2017 assessment (Fig. 11.3), and subsequently developed a population dynamics model from the conceptual model (ALBWG 2017). The use of a conceptual model improved the population dynamics model, resulting in substantially improved model diagnostics. Most importantly, an ASPM diagnostic analysis showed that the estimated catch-at-age and fixed productivity parameters (growth, mortality and stock-recruitment relationships with and without annual recruitment deviates) were able to explain trends in the adult abundance index. Based on these findings, the ALBWG concluded that the 2017 base case model was able to estimate the stock production function and the effect of fishing on the abundance of the north Pacific albacore stock.

The basic components of the conceptual model were that: 1) movements of juvenile albacore were highly variable and varied by season, year, and cohort but tended to stay in temperate waters (north of 25–30°N); 2) this variable movement and hence availability of juvenile albacore to fisheries targeting them resulted in highly variable size composition data for these fisheries; 3) after maturity, adult albacore exhibited movements into subtropical waters (south of 25–30°N); 4) adult albacore tended to stay in subtropical waters but also exhibited relatively consistent seasonal movements; 5) albacore exhibited sex- and age-specific differences in mortality, growth, and distribution; and 6) sex ratios of adult albacore in subtropical waters appeared to be biased towards adult males but the degree of bias varied by longitude, with the highest proportion of adult females in the area west of 160°E.

## 2.4 Important Changes from 2023 Assessment

There were four main changes to the base case model compared to the previous assessment in 2023.

### 2.4.1 Abundance index

The ALBWG evaluated a number of abundance indices for use in the assessment. The two primary candidate indices were Japan longline Area 2, Quarter 2 (F10) and the Japan longline all ISC areas, Quarter 2 (S36). The F10 index has been used in previous assessments. The S36 index included data from all ISC areas, a much broader spatial area than that covered in F10. Model estimates and diagnostics from models fitted to each index were similar, despite the potential of the S36 index to be a better representation of the total population. The age structured production model diagnostic showed that the F10 index had information on population scale while the S36 index did not. Thus, the ALBWG agreed to use the F10 index as the primary index of abundance similar to the 2023 assessment. The 2026 F10 index had a slightly different trend relative to the version used in 2023, particularly for the early years of the time series (2004-2006). These differences are likely due to the addition of data from 2022-2024 as well as a slight westward expansion of the spatial extend of Area 2 data.

### 2.4.2 Japan longline fleet structure

In the 2023 assessment, JPLL Quarter 1, Areas 1 and 3 data were modeled as two separate fleets representing juvenile and adult components to improve fits to the size composition data (juveniles < 85cm; adults > 85cm). For the current assessment, the ALBWG evaluated alternative model configurations that either retained this separation of the size composition data or combined the data while estimating time-varying age-based selectivity. Results indicated that separating the fleets did not improve the fits to the size composition data nor eliminate the need to estimate time-varying selectivity. As a result the ALBWG agreed to combine the juvenile and adult components into one fleet in the model, consistent with the fleet structure used in the 2020 assessment.

### 2.4.3 Time-varying Selectivity

The 2026 assessment estimated time-varying age based selectivity, as was done in the 2023 assessment. However, the ALBWG decided to estimate the time-varying selectivity with the two dimensional autoregressive (2dAR) option (Xu *et al.* 2019) for this assessment. In contrast, the 2023 assessment estimated time-varying selectivity with time blocks, which resulted in unstable parameter estimates, particularly with parameters that varied year to year.

### 2.4.4 China and Vanuatu size composition data

The ALBWG investigated modeling selectivity of the CNLL and VULL fleets. For previous assessments, size composition data were available for these fleets but were not fitted in the base case models. Instead, the selectivities for these fleets were mirrored to other fleets with similar operations. Size composition data from these two fleets were submitted for the assessment, and the catch amounts for these fleets have been relatively high in the past. However, there was uncertainty about the methods used to generate the size composition data. For this assessment, a number of different options were evaluated and the ALBWG decided to estimate selectivity for the CNLL Areas 3 and 5 fleet, which improved model fit, and mirror the selectivities for CNLL Areas 2 and 4 and VULL to the TWLL fleet.

# 3 DATA

Three types of data were used in this assessment: fishery-specific catches, size compositions, and abundance indices. Although data prior to 1994 were available, data for this assessment were compiled from 1994 through 2024 because the ALBWG agreed to follow the decision made for previous assessments (e.g. (ALBWG 2020, 2023a)) and start the base case model in 1994. Therefore, only data from 1994–2024 are shown in this section. Data sources and temporal coverage of the available datasets are summarized in Fig. 11.4.

## 3.1 Spatial Stratification

The geographic area of this assessment is the Pacific Ocean north of the equator from 0° to 55°N and from 120°E to 100°W (Fig. 11.4). This area includes all of the known catches of north Pacific albacore from 1994 through 2021. The base case model is not spatially explicit but instead used a fleets-as-areas approach (Hurtado-Ferro *et al.* 2014a). Fisheries were defined using multiple criteria, including fishing area, and therefore implicitly included spatial inferences (Table 10.1). Analyses of fishing operations and size composition data from JPLL and USLL vessels in the north Pacific showed that there were five areas with relatively consistent size distributions of albacore (ALBWG 2016; Ochi *et al.* 2016; Teo 2016). These five fishing areas were used to define fisheries in the base case model (Fig. 11.5).

## 3.2 Temporal Stratification

The time frame of the 2026 assessment was 1994−2024. Catch and size composition data were compiled into quarters (Q1: Jan−Mar, Q2 Apr−Jun, Q3: Jul−Sep, Q4: Oct−Dec) and a quarterly time step was used in the base case model. The 1994–2024 time frame for this assessment is an extension of the 2017 (time frame 1993-2015), 2020 (1994-2018), and 2023 (1994-2021) assessments (ALBWG 2017, 2020, 2023a) but is substantially shorter than the time frames used for earlier assessments, which had start years of 1966 (e.g. ALBWG 2014). Although the catch time series extended back to at least 1952 for some fisheries, a start year of 1994 was used because previous assessments had identified issues with the data and model parameters prior to 1994, especially during the 1980s and early 1990s (ALBWG 2014, 2017). These issues, still unresolved, included: 1) unaccounted catch and bycatch of high seas driftnet vessels during the 1980s and early 1990s; 2) a large proportion of size samples from Japanese longline vessels during the 1980s and early 1990s consisted of large albacore (≥100 cm FL) that were poorly fit with reasonable selectivity processes; 3) these observations of large albacore may be due to differences in growth, especially the $L_{inf}$ parameter, during the 1980s and early 1990s; and 4) conflicts between poorly fit size composition data and the primary longline indices during the 1980s and early 1990s. Most importantly, starting the base case model in 1994 allowed the ALBWG to estimate population scale from the adult albacore index, which was informative on population scale. In addition, starting the model in 1994 allowed the ALBWG to avoid modelling potentially unrepresentative size composition data from the 1980s and early 1990s that may be misinformative on population scale.

## 3.3 Fleet Definitions

Thirty-five fishing fleets were defined for the assessment on the basis of gear, fishing area, season, and unit of catch (numbers or weight), and all catch and effort data were allocated to these fleets (Table 10.1). The aim was to define relatively homogeneous fisheries with greater differences in selectivity and catchability between fisheries than temporal changes in these parameters within fleets. This approach allowed the ALBWG to use differences in selectivity between fleets as proxies for movement between fishing areas (Hurtado-Ferro *et al.* 2014a; Waterhouse *et al.* 2014) since movement information is not available. These fleets consisted primarily of 28 longline fleets from Japan (F1–F18), USA (F24 & F25), Chinese-Taipei (F26 & F27), Korea (F28), China (F29 & F30), and Vanuatu (F31 & F32) and others (F33) (Table 10.1). There were also five pole-and-line fleets from Japan (F19–F23), and the surface gears (primarily troll and pole-and-line) from Canada, Mexico, and the USA, which were combined into a single EPO surface fleet (F34). In addition, high seas drift net catches from Japan, Korea, and Chinese-Taipei, which were important in the past but had zero catch during the modeling period, and catch from all other miscellaneous gears (e.g., purse-seine) from Japan and Chinese-Taipei were combined into a single miscellaneous fleet (F35). The approximate fishing area of each fleet can be deduced from Table 10.1 and Fig. 11.5.

## 3.4 Catch

Estimates of total catch in each fleet were compiled by calendar year and quarter for 1994 – 2024 (Fig. 11.1). Catch was reported and compiled in original units consisting of weight in metric tons (t) or 1000s of fish (Table 10.1).

## 3.5 Relative Abundance Indices

The ALBWG reviewed five abundance indices, three from JPLL (Ijima *et al.* 2025; Matsubara *et al.* 2025b,a), one from TWLL (Yeh *et al.* 2025), and one from EPO surface (Kuriyama and Teo 2025a) fisheries. Based on this review and experience from previous assessments, the ALBWG decided to use the spatiotemporal abundance index from the JPLL fleet in Area 2 and Quarter 2 (F10; 1996-2024) as the index of adult abundance (Matsubara *et al.* 2025a) for the base case model. This index was used in the 2023 assessment, although it has been recalculated with three additional years of data. The F10 index used in this assessment is an appropriate index for adult albacore in the north Pacific because the majority of the adult female albacore population in the north Pacific Ocean is thought be in the western Pacific, especially Area 2 during Quarter 2 (main spawning area and season). In addition, the F10 index had good contrast and ASPM analysis results showed that an ASPM was able to fit well to the index, which the ALBWG interpreted as an indication that the F10 index was informative on both population trend and scale.

Other candidate indices were used in sensitivity runs: 1) JPLL fleet in all ISC areas (S36; 1996–2024); 2) TWLL fleet in Quarters 1 and 4 (S37; 2004-2024); and 3) EPO surface fleet in Areas 3 and 5 and Quarter 3 (F34; 1999-2024). Standardized annual values and input coefficients of variation (CVs) for the F10 index used in the base case model and indices used in sensitivity runs are shown in Tables 10.2 and 10.3, and Figs. 11.8 and 11.9. The relative weighting of the indices was controlled by adjusting the input CVs.

### 3.5.1 F10 - Japanese longline index, Area 2 and Quarter 2 (1996-2024)

The only index that was fitted in the base case model was developed using set-by-set catch (number of albacore) and effort (1000s of hooks) data from logbooks of JPLL vessels operating in Area 2 during 1996–2024 (Ijima and Tsuda 2023; Matsubayashi *et al.* 2023; Matsubara *et al.* 2025a). A Bayesian spatiotemporal zero-inflated negative binomial generalized linear mixed effects model, with first-order autoregression (AR1), was developed using the R-INLA software package (Rue *et al.* 2009; Lindgren *et al.* 2011; Martins *et al.* 2013) and used to standardize the catch and effort data. The model was described by:

$$Catch_{alb} \sim intercept + year + f(fleet, model = iid) + f(hpb, model = iid) \\ + f(vesselID, model = iid) + f(w, model = AR1) + offset(hooks/1000)$$

where $year$ was annual fixed explanatory factors, $w$ were the spatial random effects calculated with a stochastic partial differential equation approach and had a first-order temporal autoregression, and $hpb$, $fleet$, and $vesselID$ were random effects for hooks per basket, fleet, and vessel respectively. The model was fit to data from all four quarters in 1996 – 2024 but the abundance index was calculated for Quarter 2 of all years. Quarter 2 was chosen for this index because Quarter 2 is the primary spawning season and likely had a higher proportion of adult females compared to other area and quarter combinations (Section 2.4.1). Quarter 2 size composition data also appeared to have more consistent size compositions compared to the other quarters. The ALBWG observed that the proportion of sets with zero albacore catch, species composition, and Pearson residuals were biased in 1994 and 1995 (ALBWG 2019; Fujioka *et al.* 2020). Therefore, similar to previous assessments, the ALBWG decided to start the index in 1996 instead of 1994 (ALBWG 2019). In addition, the CVs of the F10 index values were estimated to be very low, and the ALBWG assumed that those values less than 0.2 were 0.2 on average. Further details on the data and standardization model can be found in Matsubara et al. (2025a) and Matsubayashi et al. (2023).

### 3.5.2 F34 - EPO surface index, Areas 3 and 5 in Quarter 3 (1999-2024; sensitivity run)

The ALBWG also considered using the standardized CPUE of the US troll and pole-and-line fishery operating in Areas 3 and 5 to represent the population trends of juvenile albacore (Kuriyama and Teo 2025a). The EPO surface fishery (F34) consists largely of US and Canadian vessels using troll and pole-and-line, and standardized CPUE of US and Canadian vessels were highly similar (Teo 2016). After filtering the data with a suite of criteria, the CPUE of the US surface fishery from quarters 2, 3 and 4 were standardized with a lognormal generalized linear model that had year, location, and quarter as fixed effects (Teo 2022). However, the ALBWG found the index from this fishery to be inappropriate for use in the base case model of the assessment. Most importantly, the EPO surface fishery is dependent on the seasonal migration of juvenile albacore into the EPO and being available to the fishery. Given that this migration is variable between years, the CPUE of this fishery also varies in part due to changes in availability. The standardization model was not able to standardize for the changes in availability. Therefore, the ALBWG only considered that this index was only suitable for a sensitivity analysis. It should be noted that in 2012 and 2023 there were no fishing regimes under the US-Canada bilateral albacore tuna treaty. This resulted in changes to the fishery operations of the EPO surface fishery, particularly in 2012, and therefore 2012 data were excluded from this index.

### 3.5.3 S36 - Japan longline index, all ISC Area in Quarter 3 (1999-2024; sensitivity run)

The ALBWG considered using the standardized CPUE from Japan longline data with data from all ISC areas (Matsubara *et al.* 2025b). This adult index for albacore was based on standardized size composition and standardized CPUE estimated with the spatiotemporal modeling R package sdmTMB. The index of abundance was standardized with a delta-generalized linear mixed effects model with vessel and location modeled as random effects and a spatiotemporal random effect. The data had much greater spatial coverage than the F10 index, and therefore thought to be a better representation of the stock's population dynamics. Models fitted to the Area 2 F10 index and this S36 index had very similar model fits and estimates, but the S36 index did not seem to have information on population scale. Therefore, the ALBWG only considered that this index was only suitable for a sensitivity analysis. The ALBWG was not able to further investigate the reasons the S36 index did not have information on population scale but will further investigate this in the future.

### 3.5.4 S37 - Taiwan juvenile longline index, Areas 3 and 5 in Quarter 3 (1995-2024; sensitivity run)

The ALBWG considered a juvenile index of abundance from the Taiwan longline fishery (Yeh *et al.* 2025). The index also fit a delta-lognormal model in sdmTMB with spatial random effects and size-specific spatiotemporal variation. The juvenile abundance increased after 2018, reaching highs in 2021-2022. The TWLL data did not seem to cover the entire range of juvenile albacore, particularly the juveniles distributed near the Japanese coast. These data are likely the most representative juvenile data set available. This index was considered for the model in addition to the F10 index in a sensitivity analysis. The idea was that there might be benefit to fitting the model to both juvenile and adult indices of abundance. The ALBWG will further investigate this index in the future.

## 3.6 Size Composition

Quarterly length composition data from 1994 through 2024 were used in this assessment. Length data were available for 22 fleets in the base case model (Table 10.1 and Figs. 11.10-11.11) and were compiled into 2-cm size bins, ranging from 26 to 142 cm FL, where the labels are the lower boundary of each bin. Most of these fleets exhibited clear modes when lengths were aggregated across quarters and years (Fig. 11.10). The length data for the JPPL fleets (F19 – F23) exhibited exceptionally high variability in the number of modes and mean sizes between quarters and years. The length frequency observations were the estimated catch-at-size (i.e., size compositions were raised to the catch) for the fleets with size composition data and these size composition data were fitted in the base case model (Table 10.1). The exceptions are the size composition data for CNLL and VULL. The ALBWG did not receive details on the calculation of these size composition data, although only the F29 (CNLL A35) are fitted in the model. The F30 and F31 data were not fitted in the model (Fig. 11.11). Instead, it was assumed that the selectivity of these fleets were the same as other longline fleets with similar fishing operations and fishing area (Section 4.3.1).

The majority of albacore length composition data were collected through port sampling or on-board sampling by vessel crews or observers. Length data for the JPLL (F1–F4; F9–F12; F17–F18) and JPPL fleets (F19 – F23) were measured to the nearest cm at the landing ports or onboard fishing vessels from which catch-at-size data were derived (Tsuda *et al.* 2025). Fork lengths of albacore in the EPO surface fleet (F34) were compiled from port samples of the US troll and pole-and-line fisheries (Kuriyama and Teo 2025b). Although length composition data were available for the Canadian component of this fleet (2008-present), these data were not used because the USA and Canada components of the fleet overlap greatly in their fishing areas and size composition plots of both fisheries are very similar. The data from the USA component were thus considered representative of the entire fleet. Length compositions for the USLL fleet were collected by observers (Kuriyama and Teo 2025c). Albacore lengths for the TWLL fleet (F26 and F27) were measured onboard fishing vessels and compiled for 1995-2024 by the Overseas Fisheries Development Council of Chinese-Taipei (Yeh and Chang 2025). Length composition data prior to 2003 were not considered representative of catches by this fleet because they were sampled from a restricted geographic area and shorter annual time period than the spatial and temporal scope at which the fleet was operating (ALBWG 2014). Thus, only the 2003-2024 size composition data were fitted in the base case model.

## 3.7 Sex Composition

Sex ratio information for north Pacific albacore were collected with genetic methods (Craig *et al.* 2025). Sex composition data are not commonly collected by commercial fisheries and Polymerase Chain Reaction and DNA sequencing were used to determine sex, which was typically only possible through direct observation of gonads. These genetic methods were used for 1255 individual samples and the sex ratios are shown in Fig. 11.12. The sex composition data show that males reach larger sizes than females (Fig. 11.12), and that the sex ratio of males to females becomes heavily biased towards males at sizes greater than 100 cm Fork Length (Ashida *et al.* 2016; Aoki *et al.* 2023). This bias towards males at large sizes has also been observed in south Pacific albacore (Farley *et al.* 2013), and is likely due to the sex-specific differences in growth (Chen *et al.* 2012; Williams *et al.* 2012) and/or natural mortality (Kinney and Teo 2016). The sex composition data were fitted in a model sensitivity but not in the base model.

# 4 MODEL DESCRIPTION

The 2026 stock assessment of north Pacific albacore tuna was conducted using the SS modeling platform (Methot 2000; Methot and Wetzel 2013). A sex-specific, length-based, age-structured, forward-simulating, fully-integrated, statistical model was developed for the stock assessment. The specification of the base case model for north Pacific albacore followed several steps. First, the spatial and temporal extent of fleets in the assessment were defined based on analyses of the biology and historical fishing operations of albacore fisheries (ALBWG 2016, 2019). Second, the data sources and inputs for these fleets in the model, including total catch, indices of relative abundance, and size compositions were identified, collated and reviewed for completeness, trends, and outliers or unusual behaviour. Third, important biological parameters (e.g., growth, stock-recruitment relationship) were obtained from previous studies after review by the ALBWG and included in the model as fixed parameters, or estimated within the assessment model (Table 10.4). Based on these inputs, preliminary models were developed and iteratively refined through an analysis of model fits (e.g., total and component negative log-likelihoods) and diagnostic outputs (e.g., ASPM, $R_0$ profiles, Pearson residuals) (ALBWG 2023a), resulting in a base case model with several differences from the base case model in the 2023 stock assessment (ALBWG

2023b). These differences included: 1) F10 JPLL index was recalculated with data from 1996-2024 and an expanded area that matched the spatial definitions in the stock assessment rather than that defined from the historical Japanese longline data; 2) Four JPLL fleets for juvenile and adult fleets (i.e., F1 and F2 and F6 and F7) in Areas 1 and 3 and Quarter 1 in the 2023 assessment were combined into two fleets (F1 and F5 in 2026 assessment) and modeled with time-varying age-based selectivity; 3) Time-varying age-based selectivity was estimated with two-dimensional autoregressive selectivity patterns rather than assuming time blocks; and 4) Size composition data from China longline (CNLL) and Vanuatu longline (VULL) were included and one CNLL was fitted in this assessment.

## 4.1 Stock Synthesis

Stock Synthesis is a highly flexible, statistical age-structured population modeling platform that can incorporate multiple data types and account for a variety of biological, fishery, and environmental processes (Methot and Wetzel 2013). Importantly for this assessment, SS can model sex-specific growth but fit to non-sex-specific observations. Although SS was initially developed for and used in US domestic stock assessments, particularly groundfish assessments on the US west coast, its use has spread to stock assessments of large pelagic fish like tunas and sharks because of the flexibility it provides for modelling multiple data types and processes.

The SS platform consists of three subcomponents: 1) a population dynamics subcomponent that simulates the assessed population (i.e., population numbers and biomass at age) using processes such as natural and fishing mortality, and the stock-recruitment relationship; 2) an observational subcomponent that relates the modeled population dynamics to observed quantities including abundance indices and size composition data; 3) and 3) a statistical subcomponent that quantifies the fit of the observations to the simulated population using maximum likelihood methods. The 2026 north Pacific albacore assessment model was implemented using SS version 3.30.24, which is publicly available (Methot 2000; Methot and Wetzel 2013).

## 4.2 Biological and Demographic Assumptions

### 4.2.1 Maximum age

The maximum age bin in the model was 15 years based on the maximum observed age (Wells *et al.* 2013). This bin served as the accumulator for all older ages. To avoid potential biases associated with the approximation of dynamics in the accumulator age, the maximum longevity was set at an age sufficient to result in near zero fish in this age bin (≈ 1 percent of an unfished cohort).

### 4.2.2 Growth

The 2026 assessment used the same sex-specific growth curves as the base case model for the previous assessments since 2014, which were based on the study by Xu et al (2014). Sex-specific growth curves were used because studies have found that north Pacific albacore tuna exhibit sex-specific growth, with male albacore exhibiting larger size at age after maturing and growing to larger size (Chen *et al.* 2012; Xu *et al.* 2014). Xu et al. (2014) combined age-at-length data from Chen et al. (2012), who primarily aged otolith samples from the northwestern Pacific, and Wells et al. (2013), who primarily obtained samples from the central and eastern North Pacific, to develop sex-specific growth curves covering the entire north Pacific Ocean.

A von Bertalanffy growth function, as parameterized by Schnute (1981), was used to model the relationship between fork length (cm) and age for north Pacific albacore:

$$L_2 = L_{inf} + \left(L_1 - L_{inf}\right) * e^{-K(A_2 - A_1)}$$

where $L_1$ and $L_2$ are the sizes associated with ages, $A_1$ and $A_2$, respectively, $L_{inf}$ is the asymptotic length, and $K$ is the growth coefficient.

In this assessment, $L_1$ was fixed at 43.504 and 47.563 cm for females and males at age 1, respectively (Table 10.4). The $L_{inf}$ and $K$ parameters were also fixed at sex-specific values from Xu et al. (2014) ($L_{inf}$ - female: 106.570 cm, male: 119.150 cm; K - female: 0.2976 $y^{-1}$, male: 0.2077 $y^{-1}$) (Fig. 11.13). The coefficients of variation (CVs) of size-at-age at $L_1$ (CV1) and $L_{inf}$ (CV2) were fixed at 0.06 and 0.04 for both female and male albacore in the base case model, based on estimates of these CVs during preliminary runs of the 2017 assessment. The CV1 parameter was well estimated in the preliminary runs because of the clear modal structure in juvenile size composition data and the model results were not highly sensitive to this parameter. However, the CV2 parameter was highly influential in the preliminary model results because of an interaction with the $L_{inf}$ parameter. An analysis of conditional age-at-length data found that the variability of size-at-age for older albacore was similar to juvenile albacore and that the CV was approximately 0.04 (Xu *et al.* 2014).

Sensitivity analyses on the CV2 parameter and alternative growth models were performed (Section 5.11.3).

### 4.2.3 Weight-at-length

Non sex-specific weight-length relationships are used to convert catch-at-length to weight-at-length data (Fig. 11.14). A previous study (Watanabe *et al.* 2006) reported that there were seasonal differences in the relationship between weight (kg) and fork length (cm) of north Pacific albacore. These non sex-specific seasonal weight-at-length relationships were used in this assessment (Table 10.4) and previous assessments since 2014 (ALBWG 2014) because there were no previous studies documenting sex-specific differences in the weight-length relationships of north Pacific albacore.

### 4.2.4 Natural mortality

This assessment used the same age and sex-specific parameters for *M* as the base model for the previous assessment in 2017, 2020, and 2023, which were based on study by Teo (2017) (Table 10.4). In assessments prior to 2017, *M* was assumed to be 0.3 $y^{-1}$ for both sexes at all ages but this assumption was not well supported (Kinney and Teo 2016). First, the ALBWG incorporated results from studies that used meta-analytical methods on a range of empirical relationships between M and life history parameters (Hamel 2015; Then *et al.* 2015; Kinney and Teo 2016; Teo 2017), which identified an *M* of 0.38 and 0.49 $y^{-1}$ for adult male and female albacore tuna, respectively. These results corresponded well to an independent study of tagging data, which estimated a non sex-specific *M* of 0.45–0.5 $y^{-1}$ for north Pacific albacore (Ichinokawa *et al.* 2008). Based on these results, the ALBWG assumed that the *M* of juvenile north Pacific albacore tuna followed a Lorenzen (1996) relationship between size and *M* for age-0 to age-2, with no difference between the sexes until age-3. Upon reaching age-3, the *M* for male albacore is assumed to be 0.38 $y^{-1}$ and the *M* for female albacore is assumed to be higher, reaching 0.49 $y^{-1}$, which may reflect the cost of reproduction. Sensitivity analyses on the *M* parameters were performed (Section 5.11.1).

#### 4.2.5 Sex specificity

A sex-specific (two sex) model was used for this assessment because of sex-specific differences in growth (Chen *et al.* 2012; Xu *et al.* 2014) and natural mortality (Kinney and Teo 2016; Teo 2017) of north Pacific albacore. In addition, males predominate in longline catches of large, mature albacore from Japanese research and training vessels, while juveniles <85 cm generally have a sex ratio of 1:1 (Ashida *et al.* 2016). As described above, sex-specific growth curves and natural mortality were used in the base case model. However, the base case model did not include sex-specific selectivity, and sex ratio at birth was assumed to be 1:1. Sex composition data for north Pacific albacore were collected with genetic methods (Craig *et al.* 2025) and were fitted in a model sensitivity but not in the base model 5.11.3.

#### 4.2.6 Movement

This stock assessment did not have explicit spatial structure and did not explicitly model the movements of north Pacific albacore. North Pacific albacore are known to exhibit seasonal and ontogenetic movements (Ichinokawa *et al.* 2008; Childers *et al.* 2011), but it is not currently feasible to develop a spatially explicit assessment model due to the lack of well designed, and consistent tagging data. Instead, selectivity patterns for fisheries were used as a proxy for spatial structure, which helps to compensate for potential biases caused by the lack of explicit spatial structure in the assessment model (Hurtado-Ferro *et al.* 2014a). This fleets-as-areas approach entailed the collection and pre-processing of fishery data in this assessment in an area-specific fashion, especially Japanese longline fisheries, and therefore contain spatial inference (Section 3.3).

#### 4.2.7 Stock structure

The current stock assessment assumes a single stock of albacore in the north Pacific Ocean from the equator to 55°N latitude and between 120°E and 100°W longitude (Fig. 11.5). This assumption is supported by evidence from tagging, and seasonal fishing pattern studies (Suzuki *et al.* 1977; Ichinokawa *et al.* 2008; Childers *et al.* 2011). Studies of albacore population genetics (Chow and Ushiama 1995; Takagi *et al.* 2001; Montes *et al.* 2012) support the hypothesis of two stocks in the Pacific Ocean, but do not provide conclusive results on finer scale structure. More recently, a study of single nucleotide polymorphisms of north Pacific albacore from a wide range of locations suggested that the north Pacific albacore stock is best thought of as a single, well-mixed stock with limited amounts of mixture from the south Pacific albacore stock (Vaux *et al.* 2021).

#### 4.2.8 Recruitment and reproduction

North Pacific albacore were assumed to have one spawning and recruitment period in the second quarter of the year (April–June) based on histological assessments of gonadal status and maturity from the western Pacific Ocean (Chen *et al.* 2010; Ashida *et al.* 2016). Although historical circumstantial evidence supported spawning in the central Pacific Ocean near Hawaii through the third quarter of the year (Otsu and Uchida 1959), there is no recent confirmation of this spawning segment so it was not considered in the assessment. Ashida et al. (2016) also recently estimated the length at 50% maturity for female north Pacific albacore at 86 cm FL, which was approximately the expected length at age-5. Based on this finding, the ALBWG assumed that 50% of the albacore at age-5 were mature and that all fish age-6+ were mature (Fig. 4.3). This maturity ogive has been used in the previous assessments since 2006 (ALBWG 2014).

A standard Beverton-Holt stock recruitment relationship was used in this assessment. The expected annual recruitment was a function of spawning biomass with steepness ($h$), virgin recruitment ($R_0$), and unfished equilibrium spawning biomass ($SSB_0$) corresponding to $R_0$, and was assumed to follow a lognormal distribution with standard deviation $\sigma_R$ (Methot 2000; Methot and Wetzel 2013). Annual recruitment deviations were estimated based on the information available in the data and the central tendency that penalizes the log (recruitment) deviations. A log-bias adjustment factor was used to assure that the estimated log-normally distributed recruitments were mean unbiased (Methot and Taylor 2011). Recruitment variability ($\sigma_R$) was tuned and fixed at 0.48 to approximate the expected variability of base case and preliminary models, which had recruitment variability ranging from 0.4 to 0.5 depending on model configuration. The log of $R_0$, annual recruitment deviates, and the offset for the initial recruitment relative to virgin recruitment, R1 , were estimated in the base case model. The choice of estimating years with information on recruitment was based on a preliminary model run with all recruitment deviations estimated (1994 – 2024). The first few years of size composition data often contain some information on recruitment from early cohorts before 1994 and the variability of recruitment deviations often increases as the information content decreases the further back in time prior to the starting year examined (Methot and Taylor 2011). The number of years for which recruitments may be observed from the early cohorts was set at 10, and these initial recruitment deviances were estimated in the model. Ten annual deviations were estimated prior to the start of the model in 1994 (i.e., 1984-1993). The 10-year period was chosen because early model runs showed negligible information on deviates more than 10 years prior to the beginning of the data. Bias adjustment was used to account for the reduction in information content from the data on recruitment deviations during the early and late periods. This adjustment mostly affects the estimation of uncertainty and not the population trajectory.

Steepness of the stock-recruitment relationship ($h$) was defined as the fraction of recruitment from a virgin population ($R_0$) when the spawning stock biomass is 20% of its unfished level ($SSB_0$). Recently, Lee et al. (2012) concluded that if the model is correctly specified, then steepness is estimable for relatively low productivity stocks with good contrast in spawning stock biomass. However, estimating $h$ within the assessment model for north Pacific albacore is likely to be imprecise and biased because contrast in the spawning biomass over the assessment period is relatively poor. Two independent estimates of steepness for north Pacific albacore (Brodziak *et al.* 2011; Iwata *et al.* 2011), based on the life history approach of Mangel et al. (2010), reported values of $h$ ranging from 0.84 to 0.95. Therefore, the ALBWG assumed a $h$ of 0.9 in this assessment, which was the same as for previous assessments during 2014 – 2023, and performed sensitivity analyses within a plausible range of $h$ , and estimating $h$ with a prior (Section 5.11.2). Nevertheless, the ALBWG notes that these steepness estimates are subject to considerable uncertainty and further work is needed to evaluate steepness estimates.

### 4.2.9 Initial conditions

A model must assume something about the period prior to the start of the main population dynamics period. Typically, two approaches are used to achieve this assumption. The first approach starts the model as far back as necessary to satisfy the notion that the period prior to the estimation of dynamics was in an unfished or near unfished state. However, this approach is not viable for this assessment because the base case model started in 1994 (Section 3.2). Instead, a second approach was used in which initial conditions were estimated (where possible) assuming equilibrium catch. The equilibrium catch is the catch taken from a fish stock when it is in equilibrium with fishery removals and natural mortality balanced by stable recruitment and growth. The initial fishing mortality rates in the assessment model that remove these equilibrium catches were estimated to allow the model to start at an appropriate depletion level. Initial fishing mortality rates were estimated for the F26 fleet (TWLL in Areas 3 & 5) because it captures a wide size range of albacore, but the initial fishing mortality rates were not fitted to historical catches prior to 1994. This approach allowed the model to start in 1994 at a depletion level that was consistent with the adult abundance index and size composition data without being overly constrained. In addition, the model included estimation of 10 recruitment deviations prior to 1994 to develop a non-equilibrium age structure at the start of the model time frame.

## 4.3 Fishery Dynamics

### 4.3.1 Selectivity

The base case model has a sex-specific structure, with sex-specific growth curves. However, it was assumed that female and male albacore have identical size selectivity for each fleet because sex-specific size composition data were not fitted. Selectivity curves were fleet-specific and assumed to be a function of only size for all but five fisheries (Table 10.1). Preliminary model runs indicated that size composition data of the JPLL fleet in Areas 1 and 3, Quarter 1 (F1), JPPL fleets in Areas 3 and 5 (F19–F22) and the EPO surface fishery (F34) had very strong and variable modes corresponding to juvenile age classes and could not be adequately fit using only size selectivity curves. Therefore, the selectivity curves of these five fleets were assumed to be a product of size and age, which improved model fits. The age-based selectivity was intended to capture differences in the availability of juvenile fish to the fishing gear based on movement patterns, which may vary between seasons and years.

Selectivity curves were estimated for all fisheries with representative size composition data while selectivity curves for fisheries without representative size composition data were assumed to be the same as fisheries with similar operating characteristics (season, area, gear) and estimated selectivity curves. If specific fisheries had changes in fishery operations or exhibited changes in size composition data consistent with changes in movement patterns, then selectivity was allowed to vary with time to account for these changes.

Highlights of the parameterization of the selectivity curves are briefly described below but more details can be found in Tables 10.5-10.8. Length-selectivity curves were assumed to be dome-shaped and modeled with double-normal functions for JPLL (F1-F4, F9-F12, F18), JPPL (F19-F23), USLL (F24-F25), TWLL (F26), CNLL (F29), and EPOSF (F34). One JPLL fleet (F17) was modeled with a spline function length-selectivity curve to improve model fits. The double-normal selectivity functions were configured to use four parameters: 1) peak, which is the initial length at which albacore were fully selected; 2) width of the plateau at the top; 3) width of the ascending limb of the curve; and 4) width of the descending limb of the curve. If the estimated width of the plateau at the top was negligible and tended to hit the lower bounds, then that parameter was fixed at a small value. The spline selectivity functions were configured to be three knot splines. The first and third knots were generally located near the edges of the respective size compositions, while the second knot was typically located near the midpoint between the first and third knots. However, the locations of the knots were subject to some trial and error. The values of two of the three knots were estimated relative to the value of the third knot, which was fixed at an arbitrary value. The gradients before the first knot and after the third knot were also estimated.

Selectivity curves of one JPLL (F1) fleet, four JPPL (F19-F22) fleets, and EPOSF (F34) fleet were assumed to be a product of size and age selectivities because their size composition data exhibited very strong modes corresponding to juvenile age classes (Tables 10.7 and 10.8). The size selectivity curves for these fleets were assumed to be dome-shaped and were modeled using double normal functions, which were configured as described above. The age selectivity of the juvenile age-classes (age-1 through age-5) of these six fleets were assumed to represent availability and were estimated as free parameters. Varying numbers of age-specific parameters were estimated for each fleet (Table 10.8). If the age selectivity parameter of an age class hit the upper or lower bound, that parameter was fixed at the upper or lower bound during the final model run to stabilize the optimization of the model. The interactions between the age and size selectivity functions for these fleets were difficult to visualize but resulted in substantially improved fits to their size composition data.

The selectivity curves for fleets lacking representative size composition data (F5-F8, F13-F16, F27, F28, F30-F33, and F35) were assumed to be the same as (i.e., mirrored to) closely related fleets or fleets operating in the same area (Table 10.1). For example, the selectivity of F5 was assumed to be the same as F1 because F5 was identical to F1 except for their catch units (Table 10.1).

Selectivity curves for most relative abundance indices were assumed to be the same as the fleet from which each respective index was derived. For example, size selectivity for the F10 index was assumed to be the same as the F10 fleet. However, for S36 and S37 the selectivities reflected the sizes of fish used in the index standardization process. S36 (JPLL all-ISC area) was modeled to be an index of adult abundance that uses a spatiotemporal model for catch and size composition data. Adult fish were assumed to be between 85-105cm, and the S36 size selectivity was fixed to span this size range (Fig. 11.6). S37 (TWLL) was a juvenile index of abundance, and the length selectivity was fixed to select 50% of 80cm fish with selectivity of 1 at 90cm (Fig. 11.7.

Time-varying age selectivity was estimated for four fleets (F1, F20, F21, and F34) to model the high year-to-year variability in the size composition data. The JPPL fleets (F20 and F21) variability was thought to be due to the variability in fishery operations and/or availability of different age classes of albacore in different areas at different times. These fleets also caught large amounts of albacore, and the complex selectivity patterns were added to fit the observed catch-at-age accurately. The fishing operations of the EPO surface fishery (F34) were found to have changed after 1998, with the fishery moving closer to the US West Coast during and after 1999 (Xu *et al.* 2013). The ALBWG adopted the 2dAR method (Xu *et al.* 2019) as a means of fitting size composition data well and achieving model convergence and good diagnostics. The ALBWG performed sensitivity analyses to evaluate the effect of changing this selectivity assumption (Section 5.11.6).

### 4.3.2 Catchability

Catchability, $q$, was estimated (solved analytically) assuming the abundance index was proportional to vulnerable biomass with a scaling factor of $q$. It was assumed that $q$ was constant over time for each index.

## 4.4 Data Observation Models

The current assessment model fitted three data components: 1) total catch, 2) relative abundance indices, and 3) size composition data.

The observed total catches were assumed to be observed, measured with relatively small observation error, and modeled using a lognormal error distribution with a fixed standard error (SE) of 0.05.

The relative abundance indices were assumed to follow a lognormal error distribution, with SE specified in log space, which corresponds approximately equivalent to CV (SE/estimate) in natural space. The CVs of each index are reported in Tables 10.2 and 10.3. The CVs derived from the index standardization model reflect observation errors within the standardization model and do not reflect additional process errors associated with the relationship between the unobserved vulnerable population and observed abundance indices. Therefore, an additional constant was added to the CVs of the indices, such that the average CV for any index was equivalent to 0.2.

The size composition data were assumed to follow a multinomial error distribution, with the error variance determined by the effective sample size ($effN$). Size measurements of fish are typically not obtained as random samples of fish from the entire population, but are instead highly correlated within each set or trip (Pennington *et al.* 2002). The effective sample size is usually substantially lower than the actual number of fish measured because the variance within each set or trip is substantially lower than the variance within a population. The ALBWG considered setting the initial effective sample size to the number of trips from which fish were measured to account for the lower variance and correlation within a trip relative to the population. However, most albacore fisheries only record the number of fish sampled. Therefore, an empirical analysis of the EPO surface fishery (F34) was used to relate the number of fish sampled to the number of trips. Based on this analysis, we assumed that 100 fish sampled were equivalent to a sampled trip. Size composition records with sample size of <0.1 were considered unrepresentative and removed. The input sample sizes for each fishery were further rescaled by a multiplier (0.275) so that the average input sample size for fishery with the most fish sampled (F26) was approximately 150. Therefore, the input sample sizes varied between fleet and over time, depending on the sampling that occurred for that fleet and period.

## 4.5 Data Weighting

Integrated stock assessment models fit a variety of data components, including abundance indices and size composition data. The results of these models can depend substantially on the relative weighting between different data components (Francis 2011). A statistical approach using the maximum likelihood estimates of variances or effective sample sizes to weight each data component by model fit (Deriso *et al.* 2007; Maunder 2011) tends to put too much weight on size composition data because numerous important processes such as variability in movements and selectivity are often not modeled or mis-specified. As a result, many assessments now weight different components based on expert knowledge of the data sampling, fishery operations, and biology of the stock, in order to balance or prioritize information from various data components.

Relative abundance indices were prioritized in this assessment based on the principle that relative abundance indices should be fitted well and that other data components such as size composition data should not induce poor fits to the abundance indices because abundance indices are a direct measure of population trends and scale (Francis 2011).

In addition, the ALBWG used the Francis data weighting method (TA1.8 in Francis 2011) to examine the weighting of each fleet's size composition data relative to how well the model fitted to the data. Results from preliminary models indicated that four fleets (F2, F20, F21, and F26) had size composition data that were over-weighted (i.e., Francis weighting multiplier of <1.0). The weighting to the size composition data from the F2, F20, F21, and F26 fleets were down-weighted by reducing the size composition sample size multiplier from 0.275 (Section 4.4) to 0.220, 0.241, 0.248, and 0.123, respectively. These sample size multipliers correspond to down-weighting the size composition data of these fleets by 20, 12, 10, and 55%, respectively, resulting in Francis weighting multipliers of these four fleets in the base case model of approximately 1.

## 4.6 Model Diagnostics

Model diagnostics (Carvalho *et al.* 2021) were used to assess issues associated with convergence, model structure, parameter mis-specification, and data conflicts in the 2026 base case model. The following diagnostic tools were employed in this assessment: 1) model convergence tests, 2) ASPM diagnostic, 3) R0 likelihood profiles, 4) residual analysis, 5) retrospective analysis, 6) catch-curve analysis, and 6) prediction skill.

### 4.6.1 Model convergence

Convergence to the global minima was examined by changing initial parameter values and the order of phases used in the optimization procedure. Particular attention was placed on the initial value and estimation phase of parameters, such as $R_0$, that influence population scale because these changes force the model to search over a vastly expanded portion of the likelihood surface. In addition, all initial parameter values were randomly jittered by sampling from a uniform distribution centered at input parameter values with upper and lower bounds of 10%. The optimized likelihoods, $R_0$ values, and important management quantities, were examined from 50 such model runs to ensure that these model runs did not find a solution with better likelihoods.

### 4.6.2 ASPM diagnostic

Following the proposal by Maunder and Piner (2015), the base case model was modified into an ASPM and ASPM-R (ASPM with recruitment deviates) to identify whether the catch and F10 abundance index were consistent with the estimated scale and trends in the population. Maunder and Piner (2015) stated that "When catch does explain indices with good contrast (e.g., declining and increasing trends), it suggests that a production function is apparent in the data, therefore providing evidence that the index is a reasonable proxy of stock trend". In this assessment, the base case model was modified into an ASPM by fixing the stock-recruitment relationship, sex-specific growth curves, and selectivities of all fleets to those estimated in the base case model, not estimating annual recruitment deviates so that recruitment follows the stock recruitment curve, and not fitting to the size composition data. The ASPM was subsequently modified into an ASPM-R by estimating annual recruitment deviates.

### 4.6.3 Likelihood profile on virgin recruitment ($R_0$)

Likelihood profiling over virgin recruitment ($R_0$) was used to examine the influence of each data component on the overall population scale (Lee *et al.* 2014). The unfished level of recruitment is a global scaling parameter in an SS model because it is proportional to unfished biomass. This process is used to assess whether the relative data weightings are appropriate and/or whether the model is mis-specified. The likelihood profile consisted of running a series of models with the $ln(R_0)$ parameter fixed at a range of values above and below that estimated within the model, and examining the likelihoods of the various data components. The estimated annual recruitment deviates were also changed from random deviates to a vector of deviates that summed to zero, which minimized the ability of the model to compensate for a lower fixed $R_0$ by raising the recruitment deviates, and vice versa.

### 4.6.4 Residual analysis

Model residuals (i.e., differences between observed data and expected values) were examined to evaluate model fit and performance. The residuals were first visually examined for patterns. The variances of residuals were also compared to evaluate the statistical assumptions of the observation model. If the variance of the residuals differs substantially from the assumed variance, then the relative data weightings likely were not appropriate. However, a lack of residual patterns does not ensure that the model is not mis-specified because parameter estimates can change to compensate for the mis-specification (Maunder and Punt 2013).

### 4.6.5 Retrospective Analysis

Retrospective analysis was used to identify systemic inconsistencies in population estimates given increasing or decreasing data periods. In this assessment, we performed a within-model retrospective analysis by systematically removing the terminal year of data from successive models (1 to 5 years), while maintaining the same model structure between models.

### 4.6.6 Catch Curve Analysis

Catch curve analyses are used to determine if the information from the size composition data on the population scale and trends are consistent with that from the other data in the model (Minte-Vera *et al.* 2021). Catch curve analyses are set up by fitting the model only to the size composition data and estimating all parameters except those associated with the index (i.e., catchability).

### 4.6.7 Prediction Skill

The prediction skill of the 2026 base case model was evaluated by hindcasting the model and calculating the MASE of the F10 index. Following Kell et al. (2021), the MASE of a model with time 1 to $T$ for a prediction horizon of $h$ time steps and $n + 1$ predictions from replicate models with 0 to $n$ time steps removed from the terminal end (i.e., a retrospective peel of $n$ time steps), was calculated as:

$$MASE = \frac{\frac{1}{n+1}\sum_{t=T-n}^{T}\left|y_t - \hat{y}_{t|t-h}\right|}{\frac{1}{n+1+h}\sum_{t=T-n-h}^{T}\left|y_t - y_{t-h}\right|}$$

where, the mean absolute prediction error (i.e., the numerator) was calculated as the mean of the absolute differences between the observations $y$ at time $t$ ($y_t$) and the predictions of the observations made $h$ steps previously ($\hat{y}_{t|t-h}$) for all the predictions made ($n + 1$); and scaled by the mean absolute naive prediction error (i.e., the denominator) calculated as the mean of the absolute differences between the observations $y$ at time $t$ ($y_t$) and the naive predictions of the observations made h steps previously ($y_{t-h}$) for all the observations ($n + 1 + h$) between the first time step used ($T - n - h$) and time step $T$.

A series of SS models was developed from the 2026 base case model, with a retrospective peel of 0 to 5 years and a prediction horizon of 1 to 5 years. The prediction horizons of 2 and 5 years are of special importance to this study because the terminal years of data are typically 2 years prior to the year when the assessments are performed, and the assessments are currently conducted on a 3-year cycle. For example, the terminal year for the 2026 base case model was 2024, and the next NPALB assessment is expected to be conducted in 2029. A $MASE$ of <1 indicates that the model is able to predict the SSB trends better than a naïve prediction. For the 2023 assessment, the MASE values ranged from 1.16-1.56 over horizons of 1-5 years (ALBWG 2023b).

## 4.7 Sensitivity to Model Assumptions

A series of sensitivity runs were performed to examine the effects of plausible alternative model assumptions on the assessment results, and to help identify the major axes of uncertainty in this assessment. The sensitivity analyses conducted in this assessment (Table 10.9) can be categorized into three main themes: 1) biology (e.g., natural mortality, steepness); 2) data (e.g., data weighting, alternative indices); and 3) model structure (e.g., selectivity, equilibrium catch). For each sensitivity run, female spawning stock biomass (SSB), fishing intensity (1-SPR) trajectories, and where appropriate, model fits to the data, were compared.

The model structure of the base case model for this assessment had several important changes from the 2023 base case model (Section 5.11.8). A sensitivity model was developed to represent the model structure of the 2023 base case model and used as a bridging analysis. This sensitivity model is similar to but not identical to the 2023 base case model due to changes in data preparation and model structure.

## 4.8 Fishery Impact Analysis

The impact of the surface and longline fisheries on SSB was evaluated. The fishery impact analysis was conducted using the parameterization and assumptions of the base case model and dropping the annual catches (1994-2024) from the SS base case data file one-by-one and calculating the SSB time series for each scenario. The magnitude of differences in the simulated SSB trajectories with and without fishing indicates the impact of the major fishery types on the female SSB. Due to the assumed selectivity of the gillnet and miscellaneous fleet (F35), it was included as part of the surface fisheries.

## 4.9 Future Projections

Stock projections were used to assess the impact of current and historical fishing intensity on the management objectives of IATTC and WCPFC for this stock. The software package (SSfuture C++; ssfcpp v2.0.4) was used to perform the future projections (Ijima *et al.* 2026). The ssfcpp software package is similar in principle to the SS base case model and is highly similar to the ssfcpp package used in the 2023 assessment (Ijima *et al.* 2023). In general, ssfcpp used the estimated sex-specific N-at-age and biological parameters from the base case model and projected the population forward using either a fixed F-at-age (constant F scenario) or randomly resampled F-at-age from 2005–2019 (randomly resampled F scenario), and a recruitment deviate vector sampled from a distribution consistent with the $\sigma_R$ in the base case model. It should be noted that ssfcpp incorporated three main sources of uncertainty in the projections: 1) uncertainty of N-at-age estimates in the terminal year of the base case model 2024; 2) uncertainty in the F-multipliers; and 3) uncertainty in the average virgin recruitment. Thus, ssfcpp incorporates most of the estimated uncertainty from the base case model into projections and is an improvement over the projections from previous assessments. However, it should also be noted that ssfcpp did not incorporate estimation uncertainties of the selectivity and recruitment deviate estimates. The ALBWG considered these projections to be an improvement over projections from assessments before 2023 but more improvements will still be needed in the future.

Two 10-yr projection scenarios, constant $F_{2021\text{-}2023}$ and randomly resampled F scenarios, were used to evaluate the impacts of fishing on the management objectives of IATTC and WCPFC. The randomly resampled F scenarios had F-at-age that were randomly sampled from 2005-2019. This 2005–2019 period was chosen as representative of the variability in F-at-age on north Pacific albacore, after both IATTC and WCPFC put in place current management measures (WCPFC CMM 2019-03; IATTC Resolution C-05-02) that maintain albacore fishing effort at or below the average effort levels during 2002–2004 but before recent declines in F after 2020.

Future recruitment was sampled from a distribution consistent with the expected recruitment variability ($\sigma_R$ = 0.48) of the recruitment time series (1994–2024) in the base case model. The sex-specific F-at-age time series was estimated from the base case model and used to remove albacore from the appropriate age and sex in the projected populations. Projections started in 2025 and continued for 10 years through 2034. The projected female SSB, fishing intensity, SSB / 14%$SSB_{current,F=0}$ ratios, and total biomass (age-1+) depletion were calculated for each projection. 400 initial populations were simulated by sampling from a multivariate normal distribution consistent with the estimated N-at-age in 2024 and its variance-covariance matrix. Each initial population was subsequently projected using 400 runs for 10 years. Each run used a random 10-year recruitment vector that was resampled from the distribution of expected future recruitment, which incorporated uncertainty in the stock-recruitment relationship, and expected recruitment variability. Depending on scenario, the F-at-age used was either based on the average F-at-age during 2021–2023, or randomly resampled from 2005–2019. A total of 160,000 (400 x 400) runs were performed for each projection scenario.

# 5 MODEL RESULTS

## 5.1 Model Convergence

All estimated parameters in the base case model were within the set bounds and the final gradient of the model was 2.723e-04, which is consistent with a model that converged onto a local or global minimum. Preliminary models results showed that the likelihood surface around the model convergence zone was bumpy and prone to converging onto local minima. The base case model was therefore run from the SS 'par' file, with highly precise initial values for parameters. Based on the results of 50 model runs with different initial values, the base case model likely converged to a global minimum (i.e., there was no evidence of a lack of convergence to a global minimum).

## 5.2 Model Diagnostics

### 5.2.1 Model fit of abundance indices

The base case model fitted the F10 adult abundance index adequately (Fig. 11.15 and Table 10.10). The root mean squared error (RMSE) between observed and predicted abundance indices for the F12 index were 0.238, which was approximately the sum of the input CV and variance adjustment for these indices (Table 10.10). This was important because the F10 index was the primary data source that provided information on the spawning stock biomass trends. The catchability coefficient ($q$) was solved analytically in the base case model as a single value for each index (Table 10.10).

### 5.2.2 Model fit of size composition data

Base case model fits to the size composition data were adequate. Overall, the model predicted size compositions matched the observations (Fig. 11.16). Examination of the input sample size (input N) and model estimated effective sample size (effN) also show adequate model fits (Table 10.11). A higher effN is consistent with better model fit and a mean effN of >30 is a sign of good overall model fit. In addition, the ratios of the harmonic mean of effN to the mean of input N were mostly >1, which is interpreted to mean that the base case input N did not assume less error than is evident in the model fits. The model fits to the size composition data of several fleets (F1, F2, F20, F21, F22, F26, F34), although adequate, had a ratio of the harmonic mean of effN to the mean of input N that was <2 and could be improved upon in the next assessment. Francis weighting multipliers for nearly all fisheries were ≥1, indicating that the weighting for all fisheries were not greater than suggested by model fits (Table 10.11). Three fleets (F2, F20, F26) had Francis weighting multipliers that were nearly 1. Pearson residual plots of the model fit to the size composition data did not reveal substantial patterns in residuals (Figs. 11.17-11.20). Where patterns were evident visually, the scale of the residuals was generally small, mostly lying within ± 2 standard deviations.

## 5.3 Age-structured production model (ASPM) diagnostic

The ASPM-R model had very similar scale and population trends to the base case model, while the ASPM had a slightly larger scale (Fig. 11.21).
Fits to the F10 index were similar across all three models (Fig. 11.22). RMSE values for these fits for 0.238 for the base model, 0.235 for ASPM, and 0.180 for ASPM-R (Fig. 11.22). These results showed that the estimated catch-at-age and fixed productivity parameters (i.e., growth, natural mortality, and spawner-recruit relationship) were able to explain overall trends in the F10 index but the addition of process error in the form of annual recruitment deviates improves the model fit. This finding in turn means that the base case model was able to estimate the stock production function and the effect of fishing on the abundance of the north Pacific albacore stock. Similar to the previous 2017, 2020, and 2023 assessments,
the connection between catch-at-age and the F10 index adds confidence to the model and data used.

## 5.4 Likelihood Profiles on Virgin Recruitment ($R_0$)

Results of the likelihood profiling on virgin recruitment, $R_0$, for the abundance indices and size composition data components of the model are shown in Fig. 11.23. Changes in the likelihood of each data component across fixed values of $R_0$ reflect the relative information content of that component with respect to population scale. The length composition data seemed to have the most information on population scale, as indicated by larger changes in likelihood values across the range of $R_0$ values evaluated. In contrast, fits tot he F10 index were relatively sensitive to $R_0$ with similar likelihood values observed over a range of fixed $ln(R_0)$ values ranging from 11 to 13 (Fig. 11.23).

The information from the length composition data appeared to be relatively consistent with the index data. Importantly, the minima of the likelihood profile of the length composition data occurred around the same range of $R_0$ as the minima of the likelihood profile of the index data, which suggests that estimated population scales from both data sources were relatively consistent. In addition, the range of changes in the negative log-likelihood of the size composition data were only slightly larger than the range of the F10 index, which suggests that the size composition data are appropriately weighted.

The interpretation of the $R_0$ likelihood profile is complicated by the presence of estimated recruitment deviates in the model, which can partially compensate for the fixed changes in $R_0$. When $R_0$ is fixed at lower values, the estimated recruitment deviates tend to increase to maintain consistency with observed data. As a result, the influence of fixing $R_0$ on model fit is decreased, and the likelihood profile should be interpreted with caution.

Across the range of $R_0$ values considered, the ratio of estimated female SSB relative to unfished SSB remained higher than the 14%$SSB_{current,F=0}$ LRP and slightly lower than the 30%$SSB_{current,F=0}$ ThRP (Fig. 11.25). Thus, the results of this assessment with respect to the status of the stock, are relatively robust.

## 5.5 Retrospective Analysis

Successive elimination of terminal year data resulted in retrospective patterns in the estimates of spawning biomass and recruitment. Removing one to five years of terminal data resulted in changes in the results of the model (Fig. 11.26). The annualized Mohn's rho (Mohn 1999) for female SSB, recruitment, and SSB depletion of the retrospective models were calculated using the method described by Hurtado-Ferro et al. (2014b) and found to be 0.14, -0.14, and 0.06 $y^{-1}$, respectively. Analysis of preliminary models indicated that the cause of this retrospective pattern was likely the data from 2021–2024. Importantly, the estimated female SSB from all the models from this analysis remained above the 30%$SSB_{current,F=0}$ ThRP, which is consistent with the conclusion that the results of this assessment are relatively robust.

## 5.6 Catch Curve Analysis

The catch curve model resulted in similar estimated female SSB scale and temporal trends to the base case model (Fig. 11.27). However, the model fit to the F10 index was degraded in the catch curve analysis relative to the base case model (Fig. 11.28). Comparison with the ASM and ASPM-R analyses (Fig. 11.22) indicated that the catch curve analysis resulted in a highly similar estimated population scale to the ASPM-R model but was slightly lower than the ASPM model. The catch curve model also had inferior fits to the F10 index compared to both the ASPM and ASPM-R models. Overall, the catch curve analysis indicated that the information on population scale derived from the size composition data was broadly consistent with that from the abundance index, and adds confidence to the results of this assessment. However, the result also indicates that the estimated population trends are also strongly influenced by the size composition data and may be in conflict with the fine-scale temporal trends in the adult index. Future work is needed to better understand and reconcile this conflict with the adult index.

## 5.7 Prediction Skill

Importantly, the prediction skill of the 2026 base case model was improved compared to that from the 2023 base case model. The 2026 model had some predictive skill for F10 indices of abundance over horizons of 1-4 years evidenced by MASE values ranging from (0.749-0.971; Table 10.12). The prediction skill of the 2023 base case model was not significant over horizons of 1 – 5 years, with MASE of 1.16 – 1.56 (ALBWG 2023a). MASE values <1 indicate that the model has predictive skill compared to a naive forecast.

## 5.8 Model Parameter Estimates

### 5.8.1 Selectivity

Length-based selectivities are shown in Fig. 11.29. F17 had a spline form, and the rest of the fleets had dome-shaped forms (Table 10.4). F26 selected the widest size range of fish and other fleets had comparatively narrower ranges of size selectivities.

Products of age and length selectivities are shown in Fig. 11.30. Fleets F1, F20, F21, and F34 had time-varying age selectivities estimated. The time-varying age selectivities were estimated for a few ages.

### 5.8.2 Catch at age

Juvenile albacore aged 2, 3, and 4 were the largest components of north Pacific albacore catch (Figure 11.31) due to the importance of surface fisheries (primarily troll, pole-and-line, and including other miscellaneous gears).

### 5.8.3 Sex Ratio

The fraction of females in the population changes by age (Fig. 11.32) and length (Fig. 11.33). Sex ratio is approximately 1:1 until albacore reach age-3+, after which males becomes more common due to the higher *M* in females at ages-3+. This change in sex ratio is further accentuated by the differences in growth such that the sex ratio is heavily biased for albacore >100 cm FL. The heavy bias towards males at large sizes (>100 cm) has been observed in this stock and in the south Pacific albacore stock (Farley *et al.* 2013). Although the heavily biased sex ratio of large albacore may have consequences in the estimated population dynamics of this stock, the implications of this bias on estimates of management quantities, stock status determinations or the development of conservation advice, are not known.

## 5.9 Stock Assessment Results

### 5.9.1 Biomass

Estimated summary biomass (males and females at age-1+) declined at the beginning of the time series until 2004 (Fig. 11.34 and Table 10.13). Subsequently, the summary biomass fluctuated without a trend until 2018, after which the biomass increased to values higher than those at the beginning of the model time period. It should be noted that the high summary biomass estimates since 2018 also had increasing uncertainty (Fig. 11.34). Estimated female SSB exhibited a similar population trend to the summary biomass, albeit with a lag of several years, and showed an initial decline until 2007 followed by fluctuations without a clear trend through 2020 (Fig. 11.34).

### 5.9.2 Recruitment

Estimated recruitment was generally consistent with the life-history characteristics of the stock and assumptions in the base case model. Recruitment estimates did not show a clear relationship to female SSB (Fig. 11.34), which was expected given the assumed high steepness value (0.9) and the relatively weak stock-recruitment relationship typical of albacore and other tunas, where recruitment variability is largely driven by environmental conditions, and a steepness of 0.9 was assumed in this assessment.

The estimated recruitments were consistent with the expected distribution of recruitment deviations ($\sigma_R$ = 0.48), where all recruitment estimates were within the expected distribution. There were historically high recruitment estimates in 2017 (~297 million fish; 95% CI: 215–381million fish), 2019 (~292 million fish; 95% CI: 187 to 396 million fish), and 2022 (~314 million fish; 95% CI: 93-536 million fish) (Fig. 11.34). The average recruitment during the 1994 – 2021 period was about 177.7 million fish, which was slightly below virgin recruitment (193.6 million fish). Uncertainty in the recruitment estimates was relatively large because uncertainty estimated for the virgin recruitment parameter, which largely determines the population scale, was relatively large. Uncertainty in the recruitment estimates also increase towards the end of the time series because the amount of information on recruitment declines towards the end of a model. It is important to note that the recruitment estimates in the last 5 years (2020-2024) were highly uncertain and should be treated with caution.

#### 5.9.3 Fishing Intensity

Fishing intensity in this assessment is based on SPR and calculated as $F_{\%SPR}$. SPR is the ratio of the equilibrium female SSB per recruit that would result from the estimated F-at-age relative to that of an unfished population. Spawning potential ratio (SPR) was used to describe the fishing intensity on this stock. Therefore, $F_{\%SPR}$ can be used to describe the overall fishing intensity on a fish stock, with a lower $F_{\%SPR}$ indicating a higher fishing intensity (Goodyear 1993).

The average fishing intensity during 2021 – 2023 was estimated to be $F66_{\%SPR}$ (95% CI: $F74_{\%SPR}$ – $F57_{\%SPR}$), which was relatively moderate and resulted in a population with an SPR of approximately 66%. Instantaneous fishing mortality at age (F-at-age) was similar in both sexes through age-5, peaking at age-4 and declining to a low at age-6, after which males experienced higher F-at-age than females up to age 14 (Fig. 11.35). Juvenile albacore aged 2 to 4 years comprised approximately 76% of the annual catch-at-age in numbers between 1994 and 2024 (Fig. 11.31) due to the larger fishery impact of surface fisheries (primarily troll, pole-and-line), which remove juvenile fish, relative to longline fisheries, which primarily remove adult fish (Fig. 11.36).

## 5.10 Biological Reference Points

The WCPFC and IATTC are the tuna RFMOs responsible for managing the north Pacific albacore stock in the WCPO and EPO, respectively, and both have adopted similar harvest strategies and biological reference points for this stock (WCPFC HS 2023-01; IATTC Resolution C-23-02). These harvest strategies include target, threshold, and limit reference points. The target reference points are defined as F45%SPR, which is the fishing intensity that results in the stock producing a SPR of approximately 45%. The threshold and limit reference points are defined as $30\%SSB_{current,F=0}$ and $14\%SSB_{current,F=0}$, respectively, which are 30% and 14% of the current, dynamic SSB under zero fishing, and hence fluctuates with changes in recruitment.

Three key management objectives in the harvest strategies are to: 1) maintain SSB above the limit reference point, with a probability of at least 80% over the next 10 years; 2) maintain depletion of total biomass around historical (2006 – 2015) average depletion over the next 10 years; and 3) maintain fishing intensity at or below the target reference point with a probability of at least 50% over the next 10 years. In addition, both RFMOs have current management measures (WCPFC CMM 2019-03; IATTC Resolution C-05-02) that maintain albacore fishing effort at or below the average effort levels during 2002 – 2004.

Stock status was evaluated relative to the target ($F45_{\%SPR}$), threshold ($30\%SSB_{current,F=0}$), and limit ($14\%SSB_{current,F=0}$) reference points (Fig. 11.37; Table 10.14). The estimated female SSB has never fallen below the threshold and limit reference points since 1994, albeit with large uncertainty in the terminal year (2024) estimates. The historical fishing intensity was estimated to have exceeded the target reference point for most years between 1997-2018. However, the estimated fishing intensity has been declining since 2019 and has been below the target reference point for the last six years. Even when alternative hypotheses about key model uncertainties such as growth were evaluated, the point estimate of female SSB in 2024 (SSB2024) did not fall below the threshold and limit reference points (Fig. 11.37). Estimated average fishing intensity during 2021-2023 (F2021-2023) did not exceed the target reference point under the alternative hypotheses. (Fig. 11.37; Table 10.14). Average fishing intensity from 2021-2023 also did not exceed the average fishing intensity during 2002-2004 (Table 10.14).

The $SSB_{2024}$ was estimated to be approximately 60% (95% CI: 38 – 83%) of $SSB_{current,F=0}$ and 2.01 (95% CI: 1.26 – 2.76) times greater than the estimated threshold reference point and greater than the limit reference point (Table 10.14). The estimated current fishing intensity (F2021-2023) was estimated to be $F66_{\%SPR}$ (95% CI: $F74_{\%SPR}$ – $F57_{\%SPR}$) and was lower than both the $F45_{\%SPR}$ target reference point and the average fishing intensity during 2002–2004 (Table 10.14).

## 5.11 Sensitivity to Model Assumptions

The following sensitivity analyses were performed to examine the effects of plausible alternative model assumptions on the assessment results, and help identify the major axes of uncertainty in this assessment (see Table 10.9 for details).

### 5.11.1 A: Natural mortality

Natural mortality is typically considered to be a major axis of uncertainty in most stock assessments. Sensitivity model runs were performed using: 1) a fixed and constant *M* of 0.3 $y^{-1}$ for both sexes and all ages (as in the 2014 assessment); 2) a fixed and constant *M* of 0.39 and 0.48 $y^{-1}$ for males and females, respectively, of all ages; and 3) an estimated, age-specific (Lorenzen), female *M* for all ages, with the prior from Teo (2017), $M_{female} \sim \ln\mathcal{N}(-0.7258, 0.457)$, and a constant logscale offset (-0.21258) between male and female *M*.

Changing the *M* from the sex-specific M-at-age vector in the base case model to the constant 0.3 $y^{-1}$ in the 2014 assessment or estimating *M* with a prior resulted in major differences in the estimated dynamic SSB depletion, and fishing intensity of the assessment (Fig. 11.39).

The estimated female *M* was 0.599 $y^{-1}$ with a corresponding male *M* of 0.484 $y^{-1}$, although the model did not seem to converge (gradient=245.532). The results of the model estimating female *M* with a prior suggests that there may be information on M in the data but the estimated population dynamics appear to be unreasonable and substantial work needs to be done before estimating *M* in the base case model. The other fixed male and female *M* sensitivity resulted in similar estimated population dynamics to those of the base case model.

### 5.11.2 B: Stock-recruitment steepness

Steepness of the Beverton-Holt stock-recruitment relationship is also often considered a major axis of uncertainty in most stock assessments. Sensitivity model runs were performed using: 1) alternative steepness values (h = 0.75; 0.80; and 0.85) to the base case model (h = 0.90); and 2) an estimated M with the prior used in the *M* sensitivity and estimated h using a prior of $h \sim \mathcal{N}(0.9, 0.1)$. Changing the steepness values had very limited effect on the estimated scale or trends in female SSB, dynamic SSB depletion, and fishing intensity (Fig. 11.40). A similar result was reported in previous assessments. The estimated h was 0.486, although the model did not seem to converge (gradient=181.619). This was not surprising because the north Pacific albacore stock is on the relatively flat part of the stock-recruitment curve and h is generally not well estimated in such cases (Lee *et al.* 2012).

### 5.11.3 C: Growth

Growth was considered an important axis of uncertainty in previous assessments because of uncertainty in the age and growth of this stock, as well as conflicts in the size composition data. The same sex-specific growth model from the 2014-2023 assessments was used in this assessment. The model fits to the size composition data were adequate but there remained uncertainty in the growth model, especially the CV of the $L_{inf}$ parameter. Two sensitivity runs were performed with the CVs of the $L_{inf}$ parameter (CV = 0.06; and 0.08) that were larger than those parameter values in the base case model (CV = 0.04). In addition, two sensitivity models were developed that estimated growth (with and without estimating CVs) and fitted to the conditional age-at-length data from Xu *et al.* (2014) and Snodgrass *et al.* (2025). Changing the CVs on the $L_{inf}$ parameter had major effects on the scale of estimated female SSB, dynamic SSB depletion, and fishing intensity, with larger CVs leading to lower estimated SSB (Fig. 11.41). Similarly, estimating growth with CVs also resulted in major effects on the estimated population dynamics (Fig. 11.41).

### 5.11.4 D: Size composition weighting

In the base case model of this assessment, the size composition data of four fleets (F2, F20, F21, and F26) were downweighted, such that the size composition data weightings for these fisheries were consistent with their model fit (i.e., Francis multiplier of ~1). A series of sensitivity models were developed where the size composition data for each fleet were downweighted by 0.1x to understand the effect of data weighting on the size composition data. Downweighting each individual fleet did not substantially affect either population trends or scale (Fig. 11.42). The ALBWG concluded that the results of the assessment were robust to the weighting of the size composition data.

### 5.11.5 E: Index standardization models

The base case model fit to the F10 adult index of abundance. Fitting the model to only the S36 index of abundance resulted in very similar model estimates, although the ASPM and ASPM-R diagnostics showed that the S36 index did not seem have information on population scale (Fig. 11.45. Conceptually, the ALBWG expected the S36 to be the preferred index of abundance given the much broader spatial coverage of the data. It was surprising that the ASPM for this sensitivity resulted in an estimate of $R_0$ at the upper bound. The ALBWG will conduct further investigation into the factors that led to this result.

Two additional sensitivities fitted the assessment model to the F10 adult index and either the F34 EPOSF juvenile index and the S37 TWLL juvenile index. Generally, the SSB estimates were relatively similar between these sensitivities, with the greatest differences from roughly 2015-2024 (Fig. 11.43). Biomasses were above the ThRP and LRP for these model runs (Fig. 11.43). The ASPM results were similar to those from the base model for the F34 sensitivity (Fig. 11.44) and the S36 sensitivity (Fig. 11.46).

### 5.11.6 F: Selectivity

Sensitivities modified the $\sigma$ values that were fixed in the 2DAR selectivity estimation (increased by 0.25 or decreased by 0.25; the higher the $\sigma$ value, the higher the variability in selectivity estimates), turned off 2DAR selectivity estimation, estimated only length-based selectivities (without any time variation), and assumed that the USLL A24 (F24) fleet had an estimated descending limb parameter, while in the base model this parameter was fixed. The results were similar for the sensitivities (Fig. 11.47), showing that the model was robust to selectivity modeling decisions.

#### 5.11.7 G: Initial conditions

Initial conditions of the model in this assessment were relatively freely estimated from the data in the main model period (1994–2024). Although the initial fishing mortality of a fishery (F26) was estimated to represent the equilibrium catches, the choice of this initial equilibrium fleet was somewhat arbitrary. Four sensitivity models were developed with different combinations of initial equilibrium fleets: 1) F1 and F20; 2) F20 and F24; 3) F20 and F26; and 4) F26 and F34. These sensitivity models resulted in either slightly larger or highly similar estimated population scales and trends (Fig. 11.48). The ALBWG concluded that the results of the assessment were robust to the choice of initial equilibrium fleet.

#### 5.11.8 H: 2026 data with 2023 model structure

The model structure of the base case model for this assessment had several important changes from the 2023 base case model (Section 2.4). A sensitivity model was developed that followed the model structure of the 2023 base case model to the extent possible. Importantly, this sensitivity model had the 2023 model data weightings, estimated time-varying selectivities with larger time blocks (and without 2DAR). Following the model structure of the 2023 base case model resulted in a slightly higher female SSB and dynamic SSB depletion (Fig. 11.49). This comparison is difficult because the change in estimates may be more due to the change in the F10 index values (F12 in the 2023 model) rather than changes to the model configuration. Nevertheless, the ALBWG decided that information from this model would be useful for comparative purposes with the base case model.

## 5.12 Fishery Impact Analysis

Surface fisheries (primarily troll, and pole-and-line, but including gillnet and other miscellaneous gears), which tend to catch juvenile fish, have generally had a larger impact (approximately 2:1 ratio) on the north Pacific albacore stock than longline fisheries, which tend to remove adult fish (Fig. 5.28).

## 5.13 Future Projections

Stock projections were used to assess the impact of current and historical fishing intensity on the management objectives of IATTC and WCPFC for this stock. The software package (SSfuture C++; ssfcpp v2.0.4) was used to perform the future projections (Ijima *et al.* 2026). Two 10-yr projection scenarios, constant F2021-2023 and randomly resampled F2005-2019 scenarios, were used to evaluate the impacts of fishing on the management objectives of IATTC and WCPFC. Each projection scenario consisted of 160,000 (400 x 400) runs, starting in 2025 and continuing for 10 years through 2034. For each scenario, 400 initial populations, together with their stock-recruitment relationships, were simulated by sampling from the estimated N-at-age distributions in 2024. Each initial population was in turn projected using 400 runs with an F-at-age and random recruitment. Most of the uncertainties from the base case model, except for estimation uncertainties of the selectivities and recruitment deviates, were incorporated into the projections.

The ALBWG considered these projections to be an improvement over projections from previous assessments but more improvements will still be needed in the future. Depending on the scenario, the F-at-age used was either based on the average F-at-age during 2021 – 2023, or randomly resampled from 2005 – 2019. Both projection scenarios showed similar trends. The constant fishing intensity scenario showed that the current fishing intensity (F2021-2023) is expected to result in female SSB increasing to 109,384 t (95% CI: 82,915– 136,573 t) by 2034. Over the next 10 years, there was: 1) a 100.0% probability of the female SSB remaining above the 14%$SSB_{current,F=0}$ LRP for all 10 years; 2) a 86.5% probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 95.3% probability of the fishing intensity remaining at or below the F45%SPR TRP for any year (Fig. 11.50). Similarly, the randomly resampled fishing intensity scenario showed that if future fishing intensity is similar to the 2005 – 2019 period, it is expected to result in female SSB increasing to 67,340 t (95% CI: 47,082 – 87,597 t) by 2034. Over the next 10 years, there was: 1) a 99.1 % probability of the female SSB remaining above the 14%$SSB_{current,F=0}$ LRP for all 10 years; 2) a 79.9 % probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 48.8% probability of the fishing intensity remaining at or below the F45%SPR TRP for any year (Fig. 11.51).

Two harvest scenarios were projected to evaluate impacts on the management objectives of IATTC and WCPFC for this stock: 1) maintain SSB above the limit reference point, with a probability of at least 80% over the next 10 years; 2) maintain depletion of total biomass around historical (2006 – 2015) average depletion over the next 10 years; and 3) maintain fishing intensity at or below the target reference point with a probability of at least 50% over the next 10 years (WCPFC HS 2023-01; IATTC Resolution C-23-02). As a larger cohort is estimated in the latest period of the assessment, all projections show a steep increase of SSB in the first year.

# 6 STOCK STATUS

Estimated summary biomass (males and females at age-1+) declined at the beginning of the time series until 2004 (Fig. 11.34). Subsequently, the summary biomass fluctuated without a clear trend until 2018, after which the biomass increased to values higher than those at the beginning of the model time period. It should be noted that the high summary biomass estimates since 2018 also had increasing uncertainty (Fig. 11.34). These high summary biomass estimates can be largely attributed to several strong recruitment estimates in 2017 (~297 million fish; 95% CI: 215– 381million fish), 2019 (~292 million fish; 95% CI: 187 to 396 million fish), and 2022 (~314 million fish; 95% CI: 93-536 million fish) (Fig. 11.34). However, it should be noted that the recruitment estimates in the last 5 years (2020-2024) were highly uncertain and should be treated with caution. Estimated female SSB exhibited a similar trend to the summary biomass, albeit with a lag of several years, and showed an initial decline until 2007 followed by fluctuations without a clear trend through 2020 (Fig. 11.34).

The average fishing intensity during 2021 – 2023 was estimated to be $F66_{\%SPR}$ (95% CI: $F74_{\%SPR}$ – $F57_{\%SPR}$), which was relatively moderate and resulted in a population with an SPR of approximately 66%. Instantaneous fishing mortality at age (F-at-age) was similar in both sexes through age-5, peaking at age-4 and declining to a low at age-6, after which males experienced higher F-at-age than females up to age 14 (Fig. 11.35). Juvenile albacore aged 2 to 4 years comprised approximately 76% of the annual catch-at-age in numbers between 1994 and 2024 (Fig. 11.31) due to the larger fishery impact of surface fisheries (primarily troll, pole-and-line), which remove juvenile fish, relative to longline fisheries, which primarily remove adult fish (Fig. 11.36).

Stock status is depicted in relation to the target ($F45_{\%SPR}$), threshold ($30\%SSB_{current,F=0}$), and limit ($14\%SSB_{current,F=0}$) reference points (Fig. 11.34; Table 10.14). The estimated female SSB has never fallen below the threshold and limit reference points since 1994, albeit with large uncertainty in the terminal year (2024) estimates. The historical fishing intensity was estimated to have exceeded the target reference point for most years between 1997-2018. However, the estimated fishing intensity has been declining since 2019 and has been below the target reference point for the last six years. Even when alternative hypotheses about key model uncertainties such as growth were evaluated, the point estimate of female SSB in 2024 (SSB2024) did not fall below the threshold and limit reference points (Fig. 11.37). Estimated average fishing intensity during 2021-2023 (F2021-2023) did not exceed the target reference point under the alternative hypotheses. (Fig. 11.37; Table 10.14). Average fishing intensity from 2021-2023 also did not exceed the average fishing intensity during 2002-2004 (Table 10.14).

The SSB2024 was estimated to be approximately 60% (95% CI: 38 – 83%) of $SSB_{current,F=0}$ and 2.01 (95% CI: 1.26 – 2.76) times greater than the estimated threshold reference point (Table 10.14). The estimated current fishing intensity (F2021-2023) was estimated to be $F66_{\%SPR}$ (95% CI: $F74_{\%SPR}$ – $F57_{\%SPR}$) and was lower than both the $F45_{\%SPR}$ target reference point and the average fishing intensity during 2002 – 2004 (Table 10.14). Based on these findings, the following information on the status of the north Pacific albacore stock is provided:

1. The stock is virtually certain (>99% probability) not to be overfished relative to the threshold ($30\%SSB_{current,F=0}$) and limit ($14\%SSB_{current,F=0}$) reference points adopted by the WCPFC and IATTC, and
2. The stock is virtually certain (>99% probability) to not be experiencing overfishing relative to the target reference point (F45%SPR).

## 6.1 Conservation Information

The constant fishing intensity scenario showed that the current fishing intensity (F2021-2023) is expected to result in female SSB increasing to 109,384 t (95% CI: 82,915 – 136,573 t) and a $SSB/SSB_{current,F=0}$ ratio of 0.83 by 2034. Over the next 10 years, there was: 1) a 100.0% probability of the female SSB remaining above the $14\%SSB_{current,F=0}$ LRP for all 10 years; 2) a 86.5% probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 95.3% probability of the fishing intensity remaining at or below the $F45_{\%SPR}$ TRP for any year. The randomly resampled fishing intensity scenario showed that if future fishing intensity is similar to the 2005 – 2019 period, it is expected to result in female SSB increasing to 67,340 t (95% CI: 47,082 – 87,597 t) and a $SSB/SSB_{current,F=0}$ ratio of 0.52 by 2034. Over the next 10 years, there was: 1) a 99.1 % probability of the female SSB remaining above the $14\%SSB_{current,F=0}$ LRP for all 10 years; 2) a 79.9 % probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 48.8% probability of the fishing intensity remaining at or below the $F45_{\%SPR}$ TRP for any year.

Based on these findings, the following conservation information is provided:

1. If fishing intensity over the next 10 years is maintained at the current fishing intensity (F2021-2023), then female SSB is expected to increase to around 83% of $SSB_{current,F=0}$ (109,384 t) by 2034, with a 100.0% probability that female SSB will remain above the 14%$SSB_{current,F=0}$ LRP for all 10 years and the harvest strategy management objectives of the IATTC and WCPFC (IATTC Resolution C-23-02; WCPFC Harvest Strategy 2023-01) will likely be met; and

2. If fishing intensity over the next 10 years is similar to the 2005 – 2019 period, then female SSB is expected to decrease to around 52% of $SSB_{current,F=0}$ (67,340 t), with a 99.1 % probability that female SSB will remain above the 14%$SSB_{current,F=0}$ LRP for all 10 years and the harvest strategy management objectives of the IATTC and WCPFC (IATTC Resolution C-23-02; WCPFC Harvest Strategy 2023-01) will likely be met.

# 7 EXCEPTIONAL CIRCUMSTANCES

The adopted harvest strategies of the WCPFC and IATTC for North Pacific albacore tuna include provisions for the identification and evaluation of exceptional circumstances that may warrant suspension or modification of the current strategies. Consistent with this requirement, the ALBWG evaluated the adopted criteria for identifying exceptional circumstances for North Pacific albacore tuna, including indicators related to stock and fleet dynamics, application of the stock assessment, and implementation of management measures. Based on the information available and the evaluation criteria, the ALBWG found no evidence to indicate that exceptional circumstances were present with respect to the conservation and management of the stock.

# 8 KEY UNCERTAINTIES AND RESEARCH RECOMMENDATIONS

Recent research by the ALBWG have included exploring CPUE standardization methods, improvements to abundance indices, understanding growth, selectivity, and sex ratio, expanding biological sampling programs, and exploring fleet-specific data issues.

The ALBWG identified the following recommendations to improve the stock assessment model:

1. Further investigation of appropriate adult abundance index for the NPALB stock especially with respect to expanding the spatial domain of the CPUE standardization model to reduce the effect of time-varying availability on the standardized abundance index, which in the model is assumed to be proportionally influenced solely by population abundance;

2. Investigate factors that preclude estimation of population scale from the JPLL all ISC area (S36);

3. Reexamine fleet structure for the NPALB stock;

4. Evaluate potential juvenile indices from the Taiwan longline fisheries in (Areas 3/5), the Japanese pole-and-line and/or EPO surface fisheries;

5. Investigate why model estimates are very sensitive to the variability in Linf, improve growth curves, and examine regional and temporal differences in length-at-age from collected data;

6. Investigate how to better model variability in availability in size and/or age to the juvenile fisheries;

7. Investigate alternative modeling options for spawning seasonality and maturity;

8. Investigate the conflict in size composition data between fleets;

9. Investigate how to model and integrate the fleet specific sex ratio data that has been collected;

10. Estimate historical high seas drift gillnet removals by member countries;

11. Explore ocean productivity as drivers of albacore trends and dynamics.

# 9 Climate Change Considerations

Environmental variability and long-term climate change are recognized as important sources of uncertainty for the assessment and management of North Pacific albacore. As a highly migratory pelagic species, North Pacific albacore inhabit temperate transition zone waters shaped by oceanographic conditions, such as sea surface temperature, ocean productivity, frontal systems, and mixed-layer depth. These environmental drivers vary over seasonal, interannual, and decadal time scales and strongly influence albacore spatial distribution, migration patterns, habitat use, and availability to fisheries (Laurs and Lynn 1977; Polovina *et al.* 2001; Childers *et al.* 2011; Christian and Holmes 2016).

A major implication for the stock assessment is that changes in fishery Catch Per Unit Effort (CPUE) may reflect shifts in distribution and catchability, rather than just changes in abundance. Studies have demonstrated that North Pacific albacore distribution closely follows preferred thermal habitats and productive frontal regions (Polovina *et al.* 2001; Bograd *et al.* 2004; Xu *et al.* 2017). Shifts in sea surface temperature and the position of the Transition Zone Chlorophyll Front (TZCF) alter the spatial overlap between fish and fishing fleets, which weakens the assumption that CPUE is directly proportional to abundance (Polovina *et al.* 2001; Bograd *et al.* 2004; Xu *et al.* 2017).

Long-term warming and marine heatwaves are expected to further shift habitats, likely causing poleward or seasonal redistribution that affects catch patterns more than underlying biomass estimates (Kitagawa *et al.* 2004; Xu *et al.* 2013; Christian and Holmes 2016). Uncertainty also surrounds climate effects on recruitment, growth, and natural mortality. While large-scale climate processes may influence recruitment through ecosystem productivity, empirical relationships have been inconsistent and uncertain (Kiyofuji 2013; Singh *et al.* 2016, 2018; Zhang 2018).

Current assessment models treat climate influences as implicit through recruitment variability and process error rather than explicitly including environmental variables. Climate can also affect vertical habitat structure, altering fish availability to fishing gear and challenging assumptions of constant catchability (Lehodey *et al.* 2008; Williams *et al.* 2015). While the inclusion of time-varying selectivity in the stock assessment partially accounts for changing availability, climate-driven variability in habitat use remains a potentially important source of residual uncertainty.

Biological reference points used to evaluate stock status are derived from historical estimates of productivity. If climate-driven changes persist, reference points estimated under historical conditions may become less representative of future stock dynamics. This uncertainty should be considered when interpreting stock status and evaluating harvest strategy performance under non-stationary environmental conditions.

At present, available information does not support modifying the assessment model structure to explicitly include climate variables. Instead, climate change considerations are best applied to contextualize results, interpret CPUE trends, and identify key uncertainties. Monitoring environmental indicators, spatial patterns of catch and effort, and fleet behavior will be important to ensure future stock assessments remain robust under changing ocean conditions.

# 10 Tables

**Table 10.1**: Fleet definitions for the 2026 assessment of north Pacific albacore tuna. Availability of size and abundance index data is indicated in the notes. * indicates that size or index data were available but were not fitted in the base case model. Two letter country codes are used in the fishery name: JP = Japan; US = United States of America; TW = Chinese-Taipei; KR = Korea; and VU = Vanuatu. Two letter gear codes are used in the fishery name: LL = longline; PL = pole and line; SF = surface (troll, pole and line); DNmisc = drift net and miscellaneous

| ID | Fishery name | Fishery | Area | Quarter | Unit | Notes | Selectivity |
|---|---|---|---|---|---|---|---|
| F1 | F1_JPLL_A13_Q1_wt | JPLL | 1 & 3 | 1 | Tonnes | Size | Length & Age |
| F2 | F2_JPLL_A13_Q2_wt | JPLL | 1 & 3 | 2 | Tonnes | Size | Length |
| F3 | F3_JPLL_A13_Q3_wt | JPLL | 1 & 3 | 3 | Tonnes | Size | Length |
| F4 | F4_JPLL_A13_Q4_wt | JPLL | 1 & 3 | 4 | Tonnes | Size | Length |
| F5 | F5_JPLL_A13_Q1_num | JPLL | 1 & 3 | 1 | 1000s | | Mirror1 |
| F6 | F6_JPLL_A13_Q2_num | JPLL | 1 & 3 | 2 | 1000s | | Mirror2 |
| F7 | F7_JPLL_A13_Q3_num | JPLL | 1 & 3 | 3 | 1000s | | Mirror3 |
| F8 | F8_JPLL_A13_Q4_num | JPLL | 1 & 3 | 4 | 1000s | | Mirror4 |
| F9 | F9_JPLL_A2_Q1_wt | JPLL | 2 | 1 | Tonnes | Size | Length |
| F10 | F10_JPLL_A2_Q2_wt_9624 | JPLL | 2 | 2 | Tonnes | Size, Index | Length |
| F11 | F11_JPLL_A2_Q3_wt | JPLL | 2 | 3 | Tonnes | Size | Length |
| F12 | F12_JPLL_A2_Q4_wt | JPLL | 2 | 4 | Tonnes | Size | Length |
| F13 | F13_JPLL_A2_Q1_num | JPLL | 2 | 1 | 1000s | | Mirror9 |
| F14 | F14_JPLL_A2_Q2_num | JPLL | 2 | 2 | 1000s | | Mirror10 |
| F15 | F15_JPLL_A2_Q3_num | JPLL | 2 | 3 | 1000s | | Mirror11 |
| F16 | F16_JPLL_A2_Q4_num | JPLL | 2 | 4 | 1000s | | Mirror12 |
| F17 | F17_JPLL_A4_num | JPLL | 4 | All | 1000s | Size | Length |
| F18 | F18_JPLL_A5_num | JPLL | 5 | All | 1000s | Size | Length |
| F19 | F19_JPPL_A35_Q1 | JPPL | 3 & 5 | 1 | Tonnes | Size | Length & Age |
| F20 | F20_JPPL_A35_Q2 | JPPL | 3 & 5 | 2 | Tonnes | Size | Length & Age^ |
| F21 | F21_JPPL_A35_Q3 | JPPL | 3 & 5 | 3 | Tonnes | Size | Length & Age^ |
| F22 | F22_JPPL_A35_Q4 | JPPL | 3 & 5 | 4 | Tonnes | Size | Length & Age |
| F23 | F23_JPPL_A24 | JPPL | 2 & 4 | All | Tonnes | Size | Length |
| F24 | F24_USLL_A35 | USLL | 3 & 5 | All | Tonnes | Size | Length |
| F25 | F25_USLL_A24 | USLL | 2 & 4 | All | Tonnes | Size | Length |
| F26 | F26_TWLL_A35 | TWLL | 3 & 5 | All | Tonnes | Size | Length |
| F27 | F27_TWLL_A24 | TWLL | 2 & 4 | All | Tonnes | | Mirror17 |
| F28 | F28_KRLL | KRLL | All | All | Tonnes | | Mirror17 |
| F29 | F29_CNLL_A35 | CNLL | 3 & 5 | All | Tonnes | Size | |
| F30 | F30_CNLL_A24 | CNLL | 2 & 4 | All | Tonnes | Size* | Mirror17 |
| F31 | F31_VULL_mt | VULL | All | All | Tonnes | Size* | Mirror26 |
| F32 | F32_VULL_num | VULL | All | All | 1000s | | Mirror26 |
| F33 | F33_OTHLL | OTHLL | All | All | Tonnes | | Mirror26 |
| F34 | F34_EPOSF_xx24 | EPOSF | All | All | Tonnes | Size, Index* | Length & Age^ |
| F35 | F35_JPTWKR_DNMisc | JPTWKR | All | All | Tonnes | Size* | Mirror19 |
| S36 | S36_JPLL_idx_adult | JPLL | All | All | Tonnes | Index* | |
| S37 | S37_TWLL_idx_juv_AR1 | TWLL | | 1&4 | Tonnes | Index* | |
| S38 | S38_JPLL_idx_85 | JPLL | All | All | Tonnes | Index* | |
| S39 | S39_JPLL_idx_90 | JPLL | All | All | Tonnes | Index* | |
| S40 | S40_JPLL_idx_95 | JPLL | All | All | Tonnes | Index* | |
| S41 | S41_JPLL_idx_100 | JPLL | All | All | Tonnes | Index* | |

**Table 10.2**: Standardized values and input coefficients of variation (CVs) of north Pacific albacore annual abundance indices developed for the 2026 base case model for the F10 index - Japan longline in Area 2, Quarter 2. Units are number of fish per unit effort. Quarter refers to annual quarters in which the majority of catch was made in the underlying fishery, where 1 = Jan-Mar, 2 = Apr-June, 3 = July-Sept, and 4 = Oct-Dec. CVs were estimated in the standardization model and then adjusted by 0.189 for all years.

| Year | CPUE | CV |
|---|---|---|
| 1996 | 9.010 | 0.011 |
| 1997 | 11.698 | 0.011 |
| 1998 | 10.822 | 0.011 |
| 1999 | 7.755 | 0.011 |
| 2000 | 11.504 | 0.010 |
| 2001 | 7.706 | 0.011 |
| 2002 | 5.095 | 0.012 |
| 2003 | 5.169 | 0.012 |
| 2004 | 3.524 | 0.012 |
| 2005 | 5.521 | 0.011 |
| 2006 | 6.891 | 0.012 |
| 2007 | 4.246 | 0.011 |
| 2008 | 6.506 | 0.011 |
| 2009 | 4.577 | 0.011 |
| 2010 | 6.045 | 0.011 |
| 2011 | 4.778 | 0.011 |
| 2012 | 5.174 | 0.011 |
| 2013 | 5.715 | 0.010 |
| 2014 | 5.959 | 0.009 |
| 2015 | 7.121 | 0.011 |
| 2016 | 5.353 | 0.012 |
| 2017 | 4.502 | 0.010 |
| 2018 | 5.433 | 0.010 |
| 2019 | 4.290 | 0.010 |
| 2020 | 3.082 | 0.010 |
| 2021 | 7.785 | 0.011 |
| 2022 | 5.766 | 0.011 |
| 2023 | 6.647 | 0.010 |
| 2024 | 8.680 | 0.013 |

**Table 10.3**: Standardized values and input coefficients of variation (CVs) of north Pacific albacore annual abundance indices developed for sensitivity model runs. Quarter refers to annual quarters in which the majority of catch was made in the underlying fishery, where 1 = Jan-Mar, 2 = Apr-June, 3 = July-Sept, and 4 = Oct-Dec. Constant additional CVs of 0.017 and 0.077 were added to the CVs of the F34 and S37 indices in sensitivity model runs, to raise the average CV to 0.2. CV values shown here do not include these additional CVs.

| Year | F34 CPUE | F34 CV | S36 CPUE | S36 CV | S37 CPUE | S37 CV |
|---|---|---|---|---|---|---|
| 1996 | | | 218.478 | 0.200 | | |
| 1997 | | | 210.056 | 0.200 | | |
| 1998 | | | 208.002 | 0.200 | | |
| 1999 | 54.261 | 0.189 | 160.509 | 0.200 | | |
| 2000 | 66.684 | 0.191 | 241.316 | 0.200 | | |
| 2001 | 89.426 | 0.189 | 185.705 | 0.200 | | |
| 2002 | 105.815 | 0.197 | 126.001 | 0.200 | | |
| 2003 | 112.194 | 0.205 | 142.818 | 0.200 | | |
| 2004 | 138.715 | 0.207 | 135.248 | 0.200 | 1.012 | 0.162 |
| 2005 | 56.791 | 0.194 | 176.930 | 0.200 | 0.373 | 0.117 |
| 2006 | 118.259 | 0.197 | 158.146 | 0.200 | 0.843 | 0.143 |
| 2007 | 73.964 | 0.202 | 107.472 | 0.200 | 1.933 | 0.242 |
| 2008 | 75.407 | 0.204 | 119.186 | 0.200 | 0.971 | 0.189 |
| 2009 | 86.892 | 0.198 | 107.015 | 0.200 | 0.529 | 0.195 |
| 2010 | 61.557 | 0.192 | 149.153 | 0.200 | 1.339 | 0.284 |
| 2011 | 54.117 | 0.197 | 155.328 | 0.200 | 0.238 | 0.119 |
| 2012 | | | 138.551 | 0.200 | 0.741 | 0.192 |
| 2013 | 68.790 | 0.196 | 122.592 | 0.200 | 1.304 | 0.328 |
| 2014 | 64.027 | 0.210 | 127.078 | 0.200 | 0.901 | 0.281 |
| 2015 | 68.735 | 0.204 | 139.215 | 0.200 | 0.309 | 0.158 |
| 2016 | 65.654 | 0.203 | 84.371 | 0.200 | 2.286 | 0.392 |
| 2017 | 47.431 | 0.199 | 85.367 | 0.200 | 0.794 | 0.261 |
| 2018 | 65.596 | 0.202 | 95.556 | 0.200 | 0.345 | 0.122 |
| 2019 | 82.862 | 0.201 | 82.264 | 0.200 | 0.505 | 0.134 |
| 2020 | 78.967 | 0.204 | 43.607 | 0.200 | 2.025 | 0.219 |
| 2021 | 75.845 | 0.201 | 120.379 | 0.200 | 1.036 | 0.152 |
| 2022 | 95.542 | 0.196 | 109.439 | 0.200 | 1.075 | 0.163 |
| 2023 | 43.974 | 0.204 | 122.349 | 0.200 | 1.501 | 0.191 |
| 2024 | 94.910 | 0.213 | 170.754 | 0.200 | 0.941 | 0.156 |

**Table 10.4**: Key life history parameters and model structures used in the base case model.

| Parameter | Value | Comments | Source |
|---|---|---|---|
| Natural mortality (M) | Female age-0: 1.36 $y^{-1}$<br>Female age-1: 0.56 $y^{-1}$<br>Female age-2: 0.45 $y^{-1}$<br>Female age-3+: 0.48 $y^{-1}$<br>Male age-0: 1.36 $y^{-1}$<br>Male age-1: 0.56 $y^{-1}$<br>Male age-2: 0.45 $y^{-1}$<br>Male age-3+: 0.39 $y^{-1}$ | Fixed parameter | Teo (2017) |
| Length at age-1 (L_1) | Female: 43.504 cm<br>Male: 47.563 cm | Fixed parameter | Xu et al. (2014) |
| Asymptotic length (L_inf) | Female: 106.57 cm<br>Male: 119.15 cm | Fixed parameter | Xu et al. (2014) |
| Growth rate (k) | Female: 0.29763 $y^{-1}$<br>Male: 0.20769 $y^{-1}$ | Fixed parameter | Xu et al. (2014) |
| CV of L_1 | 0.06 | Non sex-specific, fixed parameter | ALBWG (2014) |
| CV of L_inf | 0.04 | Non sex-specific, fixed parameter | ALBWG (2014) |
| Weight-at-length – Q1 | WL (kg) = 8.7 * 10-5 L (cm) 2.67 | Non sex-specific, fixed parameters | Watanable et al. (2006) |
| Weight-at-length – Q2 | WL (kg) = 3.9 * 10-5 L (cm) 2.84 | Non sex-specific, fixed parameters | Watanable et al. (2006) |
| Weight-at-length – Q3 | WL (kg) = 2.1 * 10-5 L (cm) 2.99 | Non sex-specific, fixed parameters | Watanable et al. (2006) |
| Weight-at-length – Q4 | WL (kg) = 2.8* 10-5 L (cm) 2.92 | Non sex-specific, fixed parameters | Watanable et al. (2006) |
| Maturity | 50% at age-5, 100% age-6+ | Fixed parameters | Ueyanagi (1957); Chen et al. (2016); |
| Fecundity | Proportional to spawning biomass | Fixed parameters | Ueyanagi (1957) |
| Spawning season | 2 | Model structure | Ueyanagi (1957); Chen et al. (2010); Ashida et al. (2016) |
| Spawner-recruit relationship | Beverton-Holt | Model structure | |
| Spawner-recruit steepness (h) | 0.9 | Fixed parameter | Brodziak et al. (2011); Iwata et al. (2011); ALBWG (2014) |
| Log of Recruitment at virgin biomass ln(R_0) | 12.12 | Maximum likelihood estimate | |
| Recruitment variability (σR) | 0.48 | Fixed parameter | |
| Initial age structure | 10 y | Estimated | |
| Main recruitment deviations | 1994-2024 | Estimated | |
| Selectivity | Size selectivity only (spline): F17 | Estimated (see Table 4.2 – 4.5) | |
| | Size selectivity only (dome): F2, F3, F4, F9, F10, F11, F12, F18, F23, F24, F25, F26, F29 | | |

| Parameter | Value | Comments | Source |
| --- | --- | --- | --- |
| | Size and age selectivity: F1, F19, F20, F21, F22, F34 | | |
| Catchability | | Solved analytically | |

**Table 10.5**: Double normal length selectivity parameter estimates (standard deviations in parentheses) in the base case model. Fleets shown had length-based selectivity only. Fixed parameters have NA values for the standard deviations.

| Fleet | Size at peak | Plateau width | Ascending slope | Descending slope |
|---|---|---|---|---|
| F2 | 79.63 (0.63) | -9.00 ( NA) | 3.80 (0.18) | 4.75 (0.17) |
| F3 | 84.69 (2.90) | 0.25 (2.47) | 3.65 (0.81) | 1.92 (78.03) |
| F4 | 105.71 (2.15) | -2.18 (7.74) | 5.45 (0.14) | 5.25 (8.31) |
| F9 | 115.47 (0.14) | -8.47 (13.60) | 5.83 (0.06) | -8.55 (13.26) |
| F10 | 106.02 (1.70) | -3.06 (1.96) | 4.41 (0.20) | 3.22 (1.24) |
| F11 | 108.70 (1.29) | -8.64 (9.79) | 4.98 (0.11) | 3.25 (0.79) |
| F12 | 110.48 (1.80) | -8.19 (19.16) | 5.13 (0.14) | 2.87 (1.21) |
| F18 | 111.29 (35.15) | -0.35 (36.43) | 6.26 (1.42) | 1.97 (157.13) |
| F23 | 92.55 (4.51) | -7.83 (25.63) | 4.81 (0.61) | 4.95 (1.54) |
| F24 | 95.27 (7.87) | 0.61 (44.11) | 5.88 (0.51) | 2.02 (156.28) |
| F25 | 140.70 (17.74) | 99.00 ( NA) | 5.89 (0.48) | 99.00 ( NA) |
| F26 | 87.64 (1.25) | 0.85 (59.25) | 4.96 (0.14) | 4.02 (111.92) |
| F29 | 84.68 (27.32) | -5.06 (61.37) | 3.38 (8.38) | 5.22 (8.54) |

**Table 10.6**: Spline length selectivity parameter estimates (standard deviations in parentheses) in the base case model. Knot locations were at 60, 90, and 140 cm.

| Fleet | Parameter | Value |
|---|---|---|
| F17 | Gradient Low | 0.29 (0.28) |
| F17 | Gradient High | -0.80 (0.63) |
| F17 | Value at 1st knot | -4.82 (79.88) |
| F17 | Value at 2nd knot | 5.06 (79.79) |
| F17 | Value at 3rd knot | -0.66 (80.19) |

**Table 10.7**: Double normal length selectivity parameter estimates (standard deviations in parentheses) in the base case model. Fleets shown here had both length and age selectivity selectivities estimated. Fixed parameters have NA values for the standard deviations.

| Fleet | Size at peak | Plateau width | Ascending slope | Descending slope |
|---|---|---|---|---|
| F1 | 78.43 (1.10) | 0.19 (1.47) | 3.72 (0.20) | 1.91 (38.37) |
| F19 | 87.29 (2.67) | -7.17 (35.19) | 4.81 (0.29) | -3.79 (29.93) |
| F20 | 75.47 (1.48) | -8.61 (10.53) | 5.46 (0.17) | 3.76 (0.36) |
| F21 | 54.62 (1.10) | -1.89 (0.27) | 2.36 (0.62) | 4.99 (0.31) |
| F22 | 54.64 (1.41) | -1.84 (0.17) | 2.61 (1.00) | 2.35 (0.67) |
| F34 | 67.84 (0.39) | -9.00 ( NA) | 3.80 (0.10) | 4.63 (0.09) |

**Table 10.8**: Age selectivity parameter estimates (standard deviations in parentheses) in the base case model. Fleets shown here had both length and age selectivity selectivities estimated. Each fleet had different numbers of age parameters estimated.

| Fleet | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| F1 | - | 10.46 (38.94) | -0.00 (38.95) | -0.76 (38.95) | -0.07 (38.95) | -9.70 (49.04) | 0.50 (38.95) | -8.86 (58.84) | 1.42 (38.96) |
| F19 | - | 8.38 (75.02) | -1.78 (75.03) | -5.09 (75.04) | -4.79 (75.05) | - | - | - | - |
| F20 | - | - | - | -0.85 (0.40) | - | - | - | - | - |
| F21 | - | - | -11.33 (0.44) | -0.46 (0.19) | - | - | - | - | - |
| F22 | -4.21 (78.16) | -8.24 (78.19) | 6.85 (95.87) | 6.96 (78.16) | -0.26 (297.54) | - | - | - | - |
| F34 | - | - | - | -10.71 (0.51) | -1.31 (0.15) | - | - | - | - |

**Table 10.9**: Sensitivity analyses conducted on the 2026 base case model for north Pacific albacore.

| Type | Name | Number | Description |
|---|---|---|---|
| Biological assumptions | Natural Mortality | A.1 | Fixed constant M of 0.3 across sexes and ages |
| | | A.2 | Constant M of 0.48 and 0.39 for female and male of all ages, respectively |
| | | A.3 | Estimated M with Lorenzen based on prior from Kinney and Teo (2017) |
| | Stock-recruitment steepness | B.1 | Steepness values = 0.75, 0.80, 0.85 |
| | | B.2 | Adding prior based on Brodziak et al. (2011) |
| | Growth | C.1 | CV of Linf is fixed higher (at 0.06 or 0.08 (higher than base case) |
| | | C.2 | Estimate growth parameters |
| Data inputs | Size composition weighting | D.1 | Down weighting each individual fleet |
| | | D.2 | Down weighting all fleets so input sample size is maximum 50 (currently 150) |
| | Index standardization models | E.1 | Fit to S36, with ASPM/ASPMR |
| | | E.2 | Fit to F10 and S36 (TWLL juvenile) with ASPM/ASPMR |
| | | E.3 | Fit to F10 and F34 (EPOSF juvenile) with ASPM/ASPMR |
| Model structure assumptions | Selectivity | F.1 | Different sigmas (up/down 0.25) |
| | | F.2 | Turn off 2DARs |
| | | F.3 | No age selectivities |
| | | F.4 | Assuming USLL A24 has an estimated descending limb in size selectivity |
| | Initial Conditions | G.1 | InitF on F1 and F20 |
| | | G.2 | InitF F20 and F24 |
| | | G.3 | InitF F20 and F26 |
| | | G.4 | InitF F26 and F34 |
| | Same model structure 2023 assessment | H.1 | Updated data |

**Table 10.10**: Analytical estimates of catchability, mean input variance, variance adjustment, and model fit (root-mean-square-error; RMSE of predictions to observations) for the F10 abundance index in the 2026 base case model.

| Index | Years | Catchability | Input CV | Var. Adj. | InputCV + Var.Adj. | RMSE |
|---|---|---|---|---|---|---|
| F10 | 1996-2024 | 8.487e-03 | 0.011 | 0.189 | 0.200 | 0.238 |

**Table 10.11**: Mean input variances (input N after variance adjustment) and model estimated mean variance (effN) of the size composition data components. Harmonic means of effN and ratio of input N to effN are also provided. A higher effN indicates a better model fit. Number of observations corresponds to the number of quarters in which size composition data were sampled in a fishery. There were no Francis weighting calculations for F29 because the data were input as superyears.

| Fleet | Number of obs. | Var. adj. | Mean input N after var.adj. | Mean effective N (effN) | Harmonic mean of effN | Harm. effN / mean inputN | Francis weighting multiplier |
|---|---|---|---|---|---|---|---|
| 1 | 31 | 0.275 | 51.576 | 165.830 | 48.599 | 0.942 | 1.808 |
| 2 | 27 | 0.220 | 22.539 | 59.730 | 28.263 | 1.254 | 0.997 |
| 3 | 25 | 0.275 | 1.595 | 23.979 | 18.148 | 11.377 | 3.741 |
| 4 | 27 | 0.275 | 28.851 | 111.985 | 62.197 | 2.156 | 1.062 |
| 9 | 29 | 0.275 | 16.182 | 146.819 | 80.942 | 5.002 | 1.364 |
| 10 | 25 | 0.275 | 16.762 | 158.783 | 75.253 | 4.489 | 2.748 |
| 11 | 24 | 0.275 | 20.644 | 181.381 | 69.974 | 3.390 | 1.051 |
| 12 | 28 | 0.275 | 12.084 | 116.107 | 75.992 | 6.289 | 3.078 |
| 17 | 73 | 0.275 | 2.002 | 75.168 | 21.034 | 10.508 | 8.120 |
| 18 | 12 | 0.275 | 0.894 | 45.938 | 32.339 | 36.182 | 9.552 |
| 19 | 6 | 0.275 | 1.947 | 19.028 | 13.461 | 6.915 | 6.494 |
| 20 | 31 | 0.241 | 10.905 | 34.182 | 10.732 | 0.984 | 0.979 |
| 21 | 29 | 0.248 | 6.857 | 18.029 | 10.914 | 1.592 | 1.000 |
| 22 | 9 | 0.275 | 6.919 | 10.423 | 4.755 | 0.687 | 2.310 |
| 23 | 25 | 0.275 | 0.860 | 13.388 | 8.993 | 10.458 | 4.907 |
| 24 | 72 | 0.275 | 0.600 | 36.581 | 16.356 | 27.280 | 12.701 |
| 25 | 116 | 0.275 | 1.068 | 63.198 | 32.752 | 30.666 | 33.596 |
| 26 | 64 | 0.123 | 12.720 | 63.064 | 21.911 | 1.723 | 0.982 |
| 29 | 5 | 0.275 | 0.275 | 307.993 | 307.993 | superyear | NA |
| 34 | 69 | 0.275 | 25.892 | 70.062 | 30.951 | 1.195 | 1.699 |

**Table 10.12**: Prediction skill of the 2026 North Pacific albacore base case model on the F10 abundance index over a horizon of 1 to 5 years and a retrospective peel of 0 to 5 years, using mean absolute scaled error (MASE) as the metric of skill.

| Horizon (year) | Mean absolute prediction error | Mean absolute naive prediction error | Mean absolute fit error | Mean absolute scaled error |
|---|---|---|---|---|
| 1 | 1.524 | 1.845 | 1.171 | 0.826 |
| 2 | 1.450 | 1.937 | 1.178 | 0.749 |
| 3 | 1.403 | 1.586 | 1.178 | 0.885 |
| 4 | 2.032 | 2.093 | 1.169 | 0.971 |
| 5 | 1.903 | 1.727 | 1.187 | 1.102 |

**Table 10.13**: Total biomass (Q1, age-1+), female spawning biomass (Q2), Threshold reference point adopted by the NC of the WCPFC (30%SSB~current,F=0~), recruitment, and fishing intensity (1-SPR) estimated in the base case model.

| Year | Age-1+ biomass (t) | SSB (t) | Threshold reference point (t) | Recruitment (x1000fish) | Fishing intensity (F%SPR) |
|---|---|---|---|---|---|
| 1994 | 840,190 | 75,125 | 50,149 | 251,376 | 54.9 |
| 1995 | 854,344 | 81,704 | 48,225 | 124,419 | 58.1 |
| 1996 | 845,715 | 93,022 | 49,858 | 251,881 | 50.6 |
| 1997 | 839,683 | 83,944 | 46,397 | 142,027 | 41.6 |
| 1998 | 806,652 | 69,345 | 41,850 | 133,618 | 47.0 |
| 1999 | 753,314 | 72,937 | 44,787 | 261,770 | 29.8 |
| 2000 | 723,246 | 63,250 | 43,815 | 163,737 | 46.6 |
| 2001 | 746,263 | 64,140 | 44,481 | 137,326 | 43.1 |
| 2002 | 722,516 | 62,148 | 44,297 | 107,313 | 37.5 |
| 2003 | 645,412 | 55,988 | 40,288 | 158,135 | 38.2 |
| 2004 | 589,465 | 61,116 | 42,856 | 232,588 | 29.6 |
| 2005 | 598,488 | 58,102 | 44,658 | 142,029 | 44.0 |
| 2006 | 638,459 | 49,798 | 41,574 | 136,126 | 43.6 |
| 2007 | 643,576 | 42,606 | 37,172 | 154,999 | 35.3 |
| 2008 | 616,569 | 40,563 | 35,418 | 187,646 | 48.9 |
| 2009 | 638,441 | 52,410 | 39,253 | 162,067 | 38.0 |
| 2010 | 647,458 | 54,896 | 40,463 | 209,520 | 44.1 |
| 2011 | 685,064 | 49,361 | 38,102 | 147,808 | 42.6 |
| 2012 | 700,817 | 47,510 | 37,157 | 100,529 | 38.7 |
| 2013 | 653,168 | 50,896 | 38,702 | 140,312 | 39.6 |
| 2014 | 603,623 | 53,342 | 39,645 | 85,268 | 40.4 |
| 2015 | 546,578 | 55,549 | 41,434 | 90,763 | 39.9 |
| 2016 | 489,443 | 54,714 | 41,513 | 188,239 | 43.7 |
| 2017 | 497,907 | 48,017 | 37,398 | 297,780 | 41.3 |
| 2018 | 601,307 | 43,185 | 34,682 | 56,436 | 42.5 |
| 2019 | 652,423 | 38,595 | 31,672 | 291,914 | 58.5 |
| 2020 | 731,605 | 36,612 | 28,031 | 152,108 | 50.4 |
| 2021 | 771,350 | 45,807 | 30,093 | 128,823 | 61.3 |
| 2022 | 780,866 | 71,590 | 39,857 | 314,422 | 68.3 |
| 2023 | 857,262 | 73,973 | 39,596 | 186,741 | 67.1 |
| 2024 | 924,157 | 84,209 | 41,933 | 180,291 | 72.0 |

**Table 10.14**: Estimates of maximum sustainable yield (MSY), female spawning stock biomass (SSB), fishing intensity (F), and reference point ratios for north Pacific albacore tuna for: 1) the base case model; 2) one important sensitivity model due to uncertainty in growth parameters; 3) a model representing an update of the 2023 base case model to 2026 data; and 4) a model representing uncertainty in the specification of initial fishing mortality.$SSB_0$, $SSB_{current,F=0}$, and $SSB_{MSY}$ are the expected female SSB of a population in the equilibrium, unfished state; in the current, dynamic, unfished state; and at MSY, respectively. The Fs in this table are indicators of fishing intensity based on spawning potential ratio (SPR) and calculated as %SPR. SPR is the ratio of the equilibrium SSB per recruit that would result from the estimated F-at-age relative to that of an unfished population. Depletion is calculated as the proportion of the age-1+ biomass during the specified period relative to an unfished age-1+ equilibrium biomass. The model representing an update of the 2023 base case model is similar to but not identical to the 2026 base case model due to changes in data preparation and model structure. †A value of >1 for the depletion ratio indicates higher age-1+ biomass in 2024 relative to the 2006–2015 period. §Higher %SPR values indicate lower fishing intensity levels. ¶Values of >1 for ratios of $F_{\%SPR}$ to $F_{\%SPR}$-based reference points indicate fishing intensity levels lower than the reference points.

| Quantity | Base Case | Growth CVold=0.06 | Update of 2023 base case model to 2026 data* | Initial Conditions initF F20 F24 |
|---|---|---|---|---|
| MSY (t) | 106,578 | 86,675 | 113,793 | 100,322 |
| $SSB_{MSY}$ (t) | 19,360 | 15,878 | 20,524 | 18,316 |
| $SSB_0$ (t) | 139,466 | 113,685 | 147,874 | 131,221 |
| $SSB_{2024}$ (t) | 84,209 | 49,547 | 96,362 | 73,236 |
| $SSB_{current, F=0}$ (2024 estimate) | 139,777 | 107,072 | 151,193 | 129,224 |
| $SSB_{2024}/SSB_{current, F=0}$ | 0.60 | 0.46 | 0.64 | 0.57 |
| $SSB_{2024}/30\%SSB_{current, F=0}$ | 2.01 | 1.54 | 2.12 | 1.89 |
| $SSB_{2024}/14\%SSB_{current, F=0}$ | 4.30 | 3.31 | 4.55 | 4.05 |
| † $Depletion_{2024}/Depletion_{2006\text{-}2015}$ | 1.45 | 1.40 | 1.61 | 1.45 |
| § $F_{\%SPR, 2021\text{-}2023}$ (%SPR) | 65.6 | 51.9 | 68.0 | 62.2 |
| § $F_{\%SPR, 2013\text{-}2023}$ (%SPR) | 50.3 | 36.7 | 53.6 | 46.6 |
| ¶ $F_{\%SPR, 2021\text{-}2023}/F_{\%SPR, MSY}$ | 4.03 | 3.17 | 4.18 | 3.80 |
| ¶ $F_{\%SPR, 2013\text{-}2023}/F45_{\%SPR}$ | 1.12 | 0.82 | 1.19 | 1.04 |
| ¶ $F_{\%SPR, 2021\text{-}2023}/F45_{\%SPR}$ | 1.46 | 1.15 | 1.51 | 1.38 |
| ¶ $F_{\%SPR, 2021\text{-}2023}/F_{\%SPR, 2002\text{-}2004}$ | 1.87 | 2.13 | 1.78 | 1.95 |

# 11 Figures

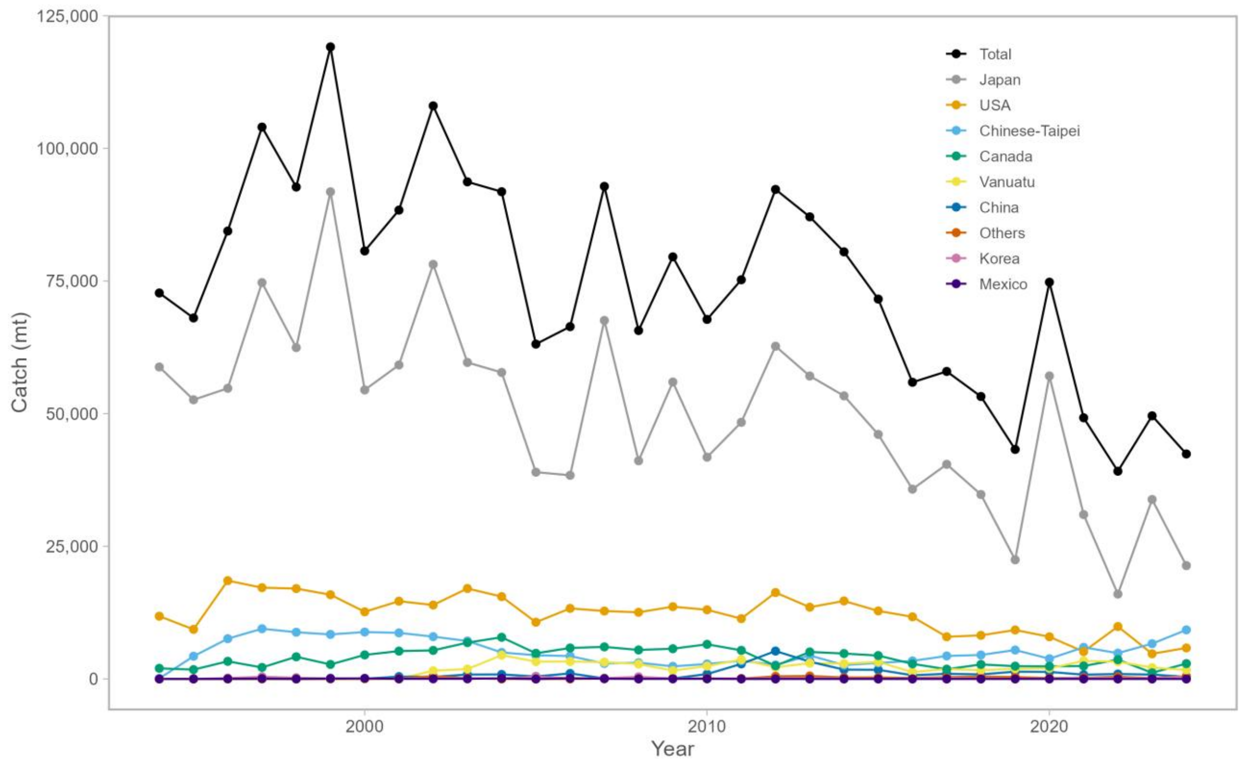


**Figure 11.1**: Estimated total annual catch of north Pacific albacore (*Thunnus alalunga*) by all countries harvesting the stock, 1994-2024. Catches in the "Others" categories includes small amount of catch by other countries such as Kiribati, Belize, Panama, and Marshall Islands.

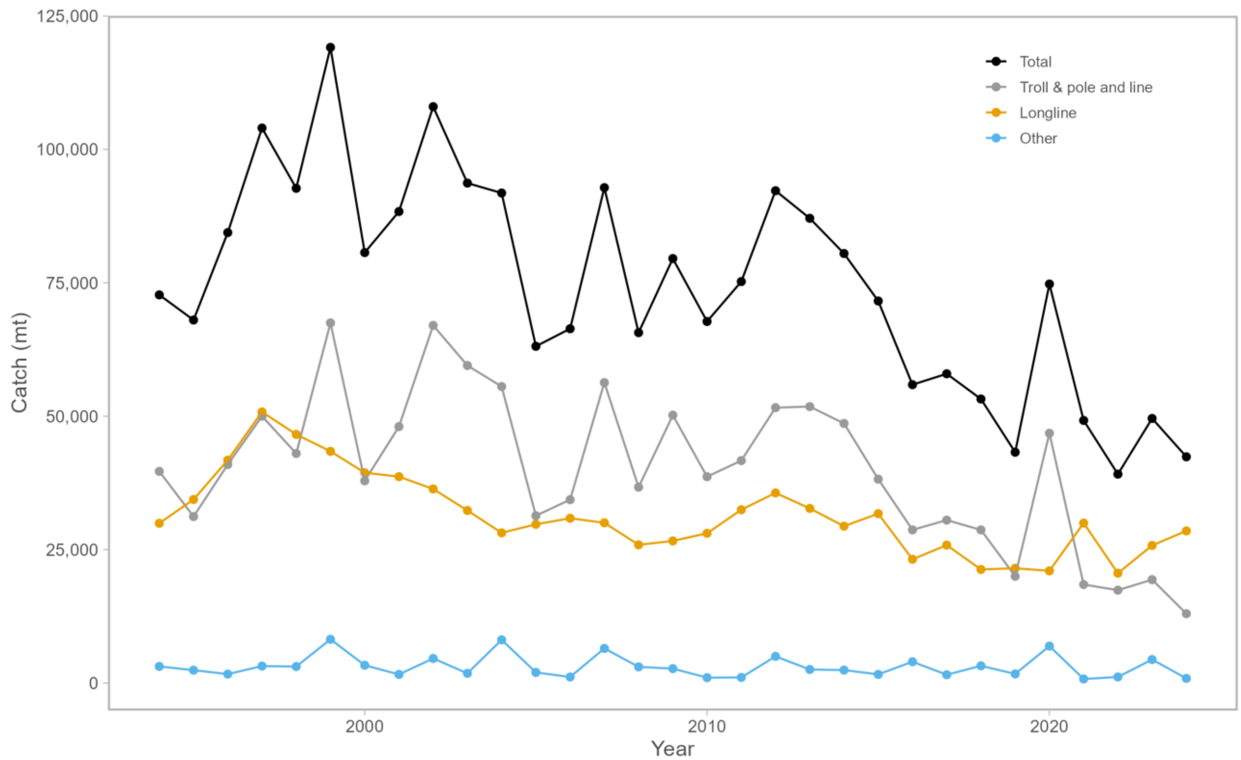


**Figure 11.2**: Estimated catches of north Pacific albacore by major gear types, 1994-2024. The Other gear category includes catches with purse seine, gillnet, hand lines, and harpoons.

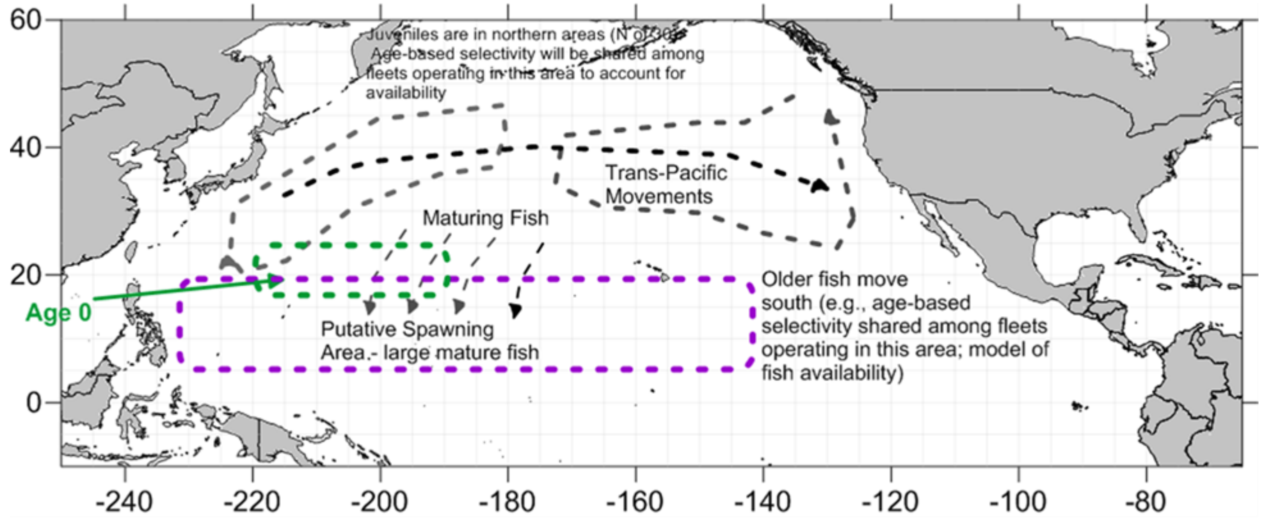


**Figure 11.3**: Conceptual model of north Pacific albacore biology and population dynamics.

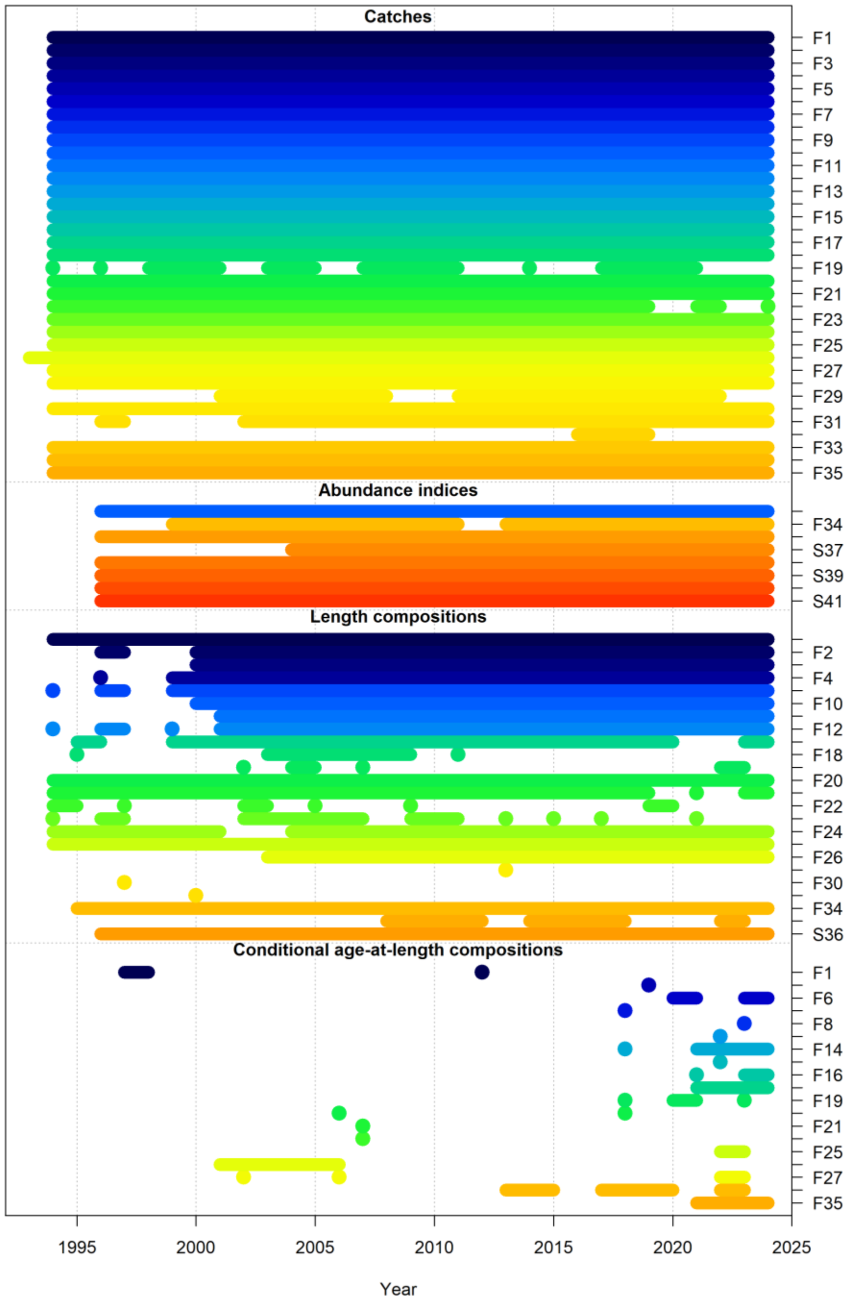


**Figure 11.4**: Temporal coverage and sources of catch, abundance indices, length composition and conditional age at length data by fleet used in the 2026 assessment of north Pacific albacore tuna.

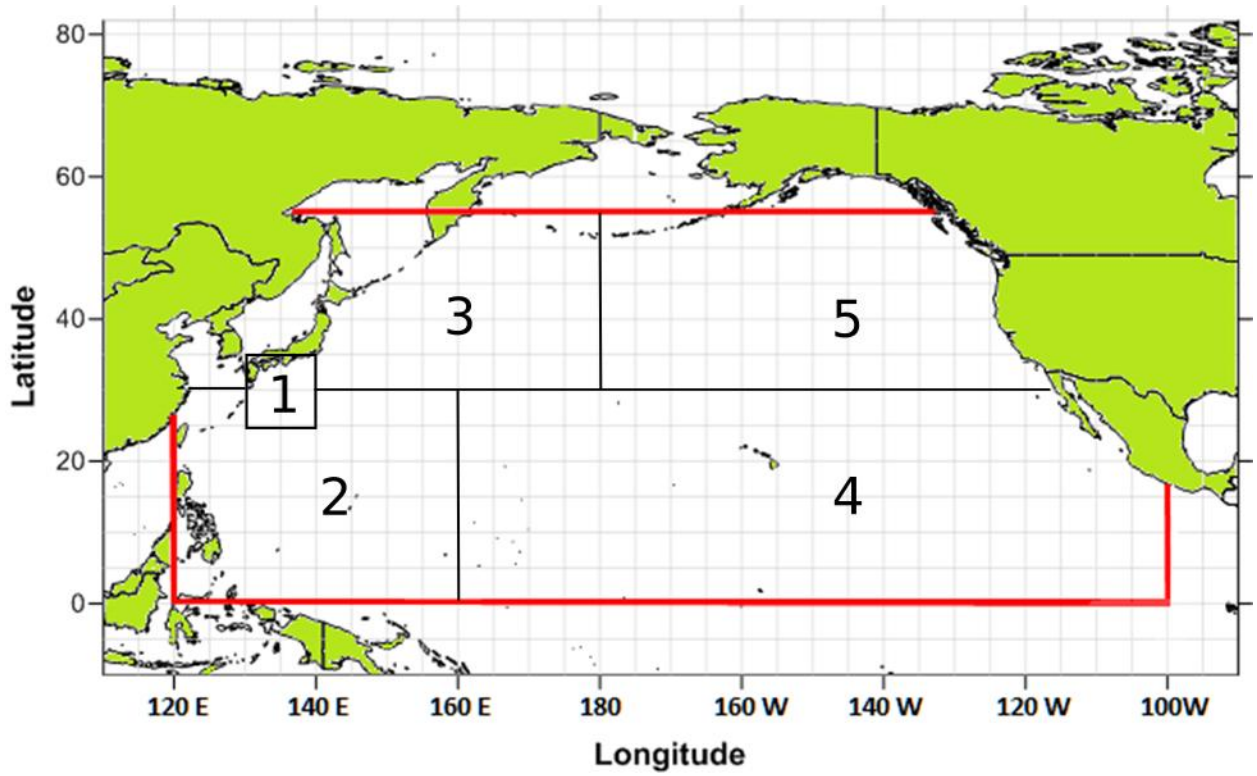


**Figure 11.5**: Spatial domain (red box) of the north Pacific albacore stock (*Thunnus alalunga*) in the 2026 stock assessment. Fishery definitions were based on five fishing areas (black boxes and numbers) defined from cluster analyses of size composition data.

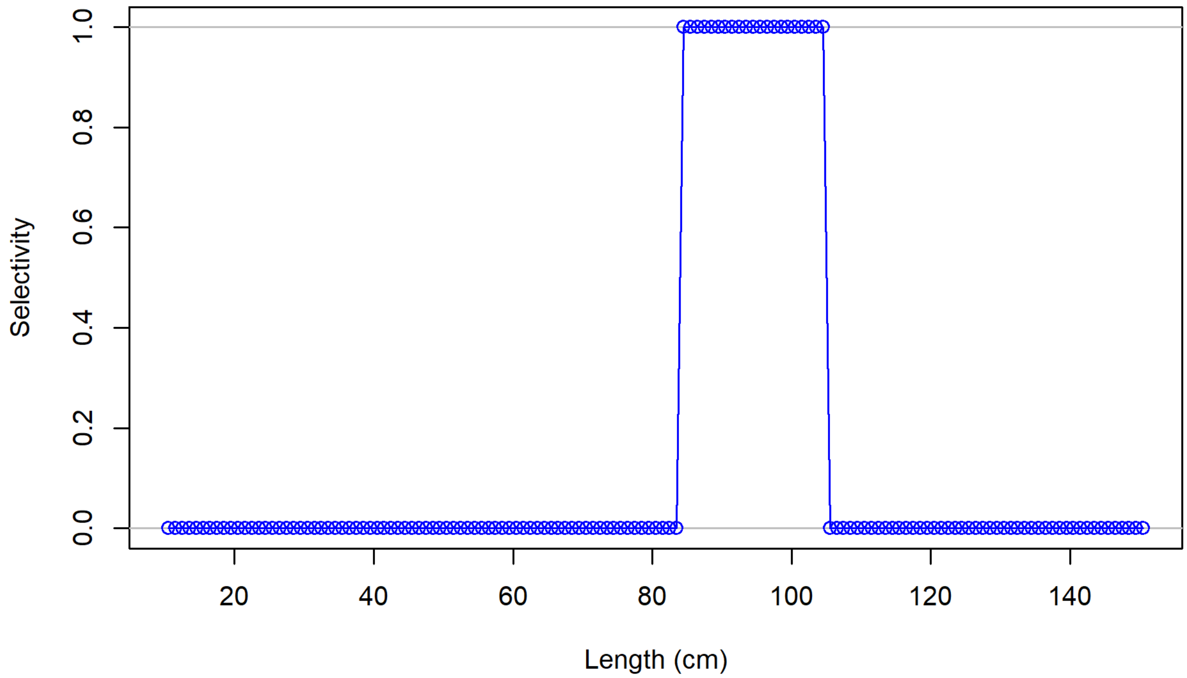


**Figure 11.6**: Length selectivity for Japan longline all ISC areas, Quarter 2 (S36) index.

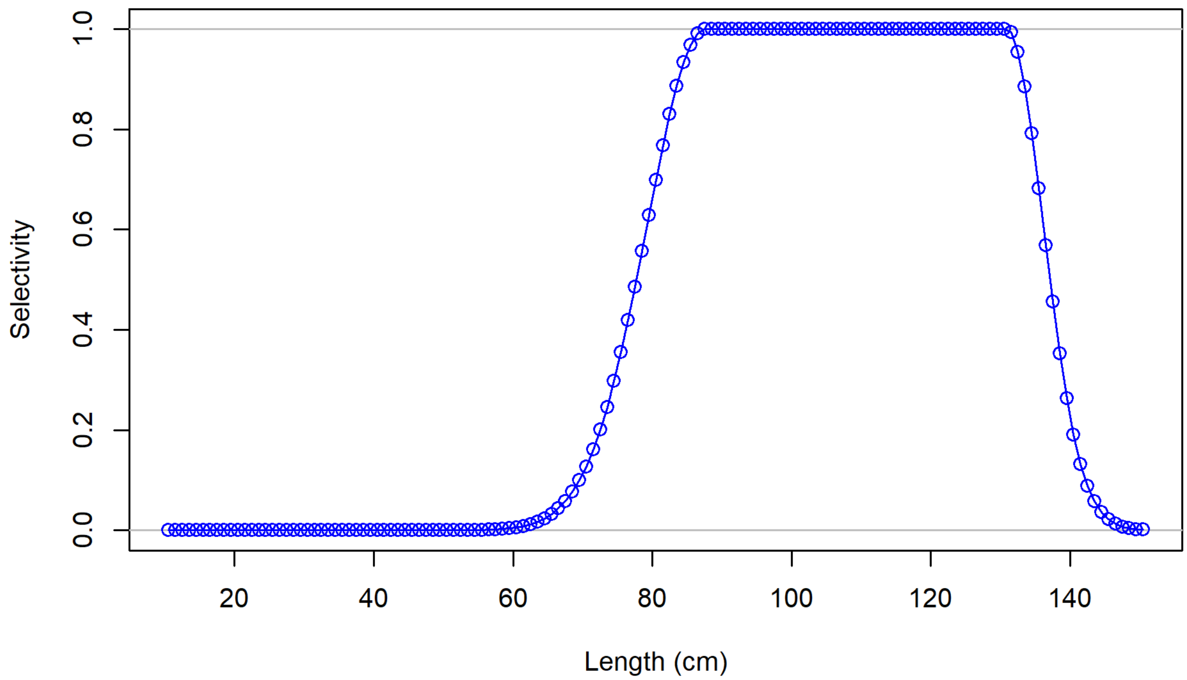


**Figure 11.7**: Length selectivity for Taiwan longline fleet in Quarters 1 and 4 (S37).

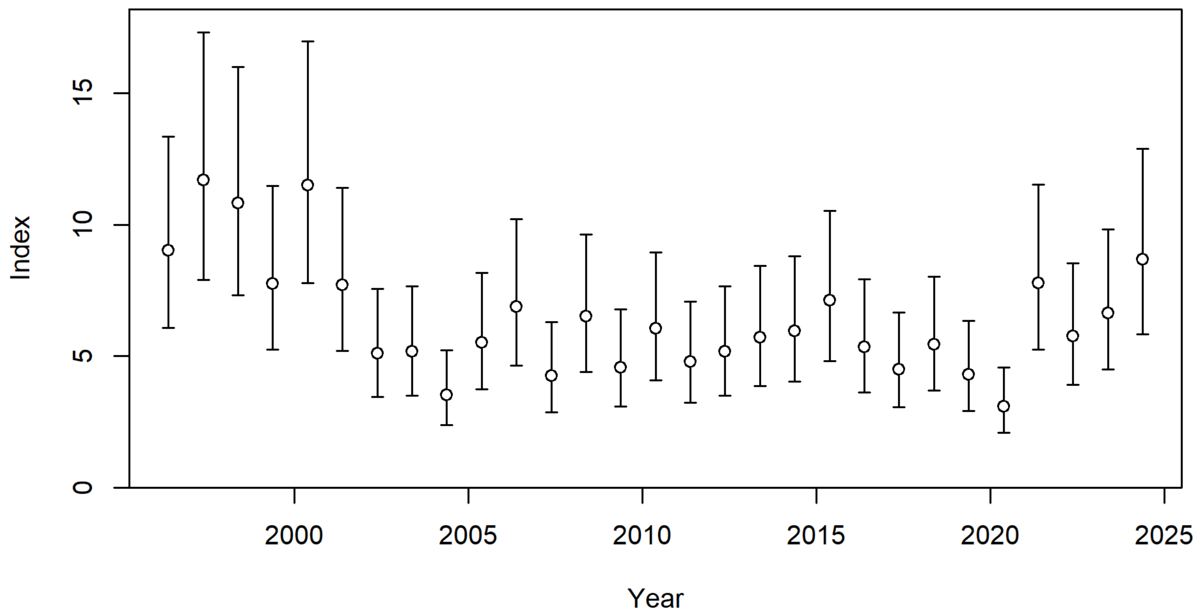


**Figure 11.8**: Trends and 95% confidence intervals of the adult index (F10) used in the base case model. Note that the 95% confidence intervals are based on the model assumption of lognormal error, and include both input and additional coefficients of variation (CVs).

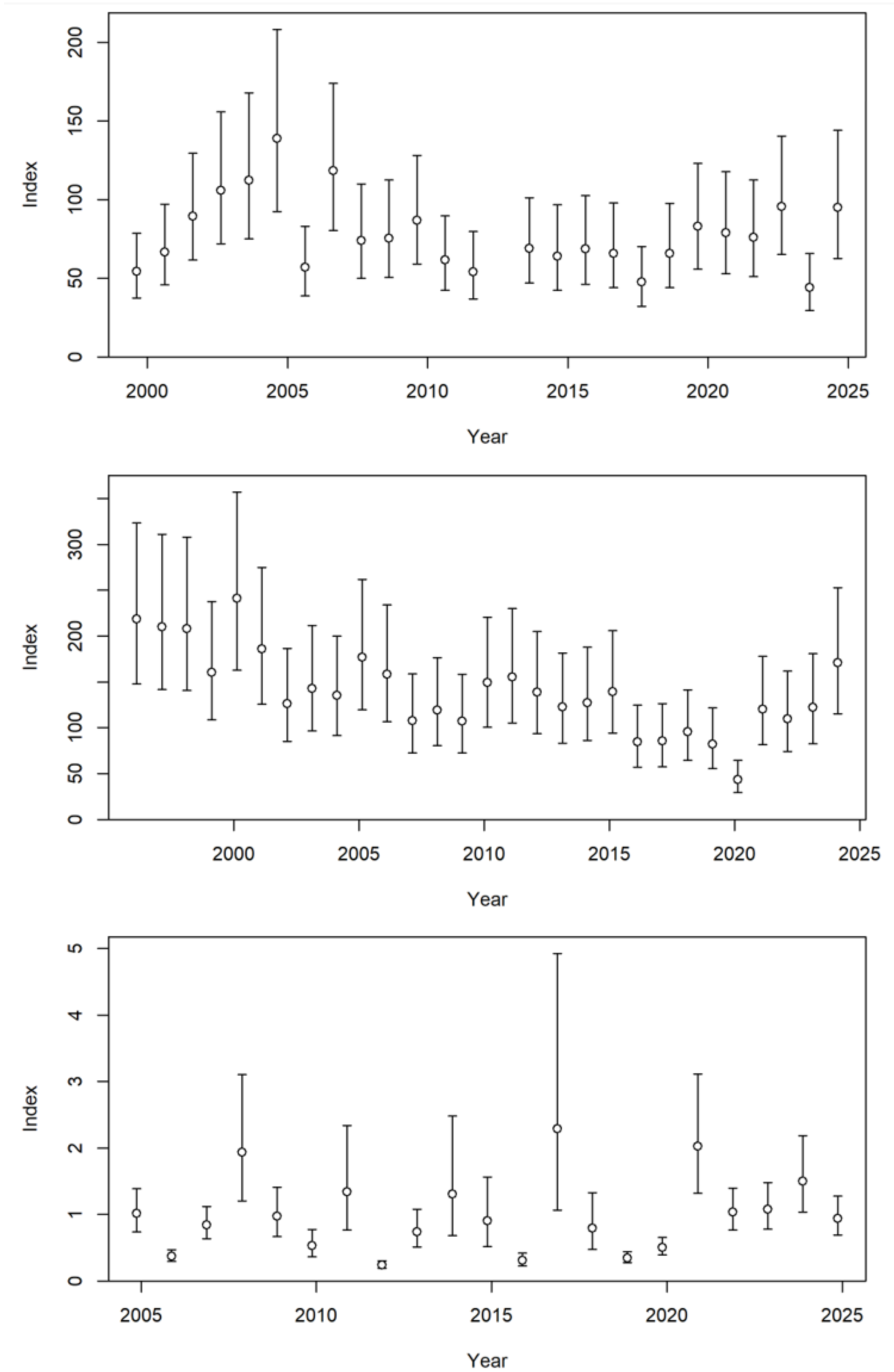


**Figure 11.9**: Trends and 95% confidence intervals of the indices (F34-top; S36-middle; S37-bottom) used in sensitivity model runs. Note that the 95% confidence intervals are based on the model assumption of lognormal error, and include both input and additional coefficients of variation (CVs).

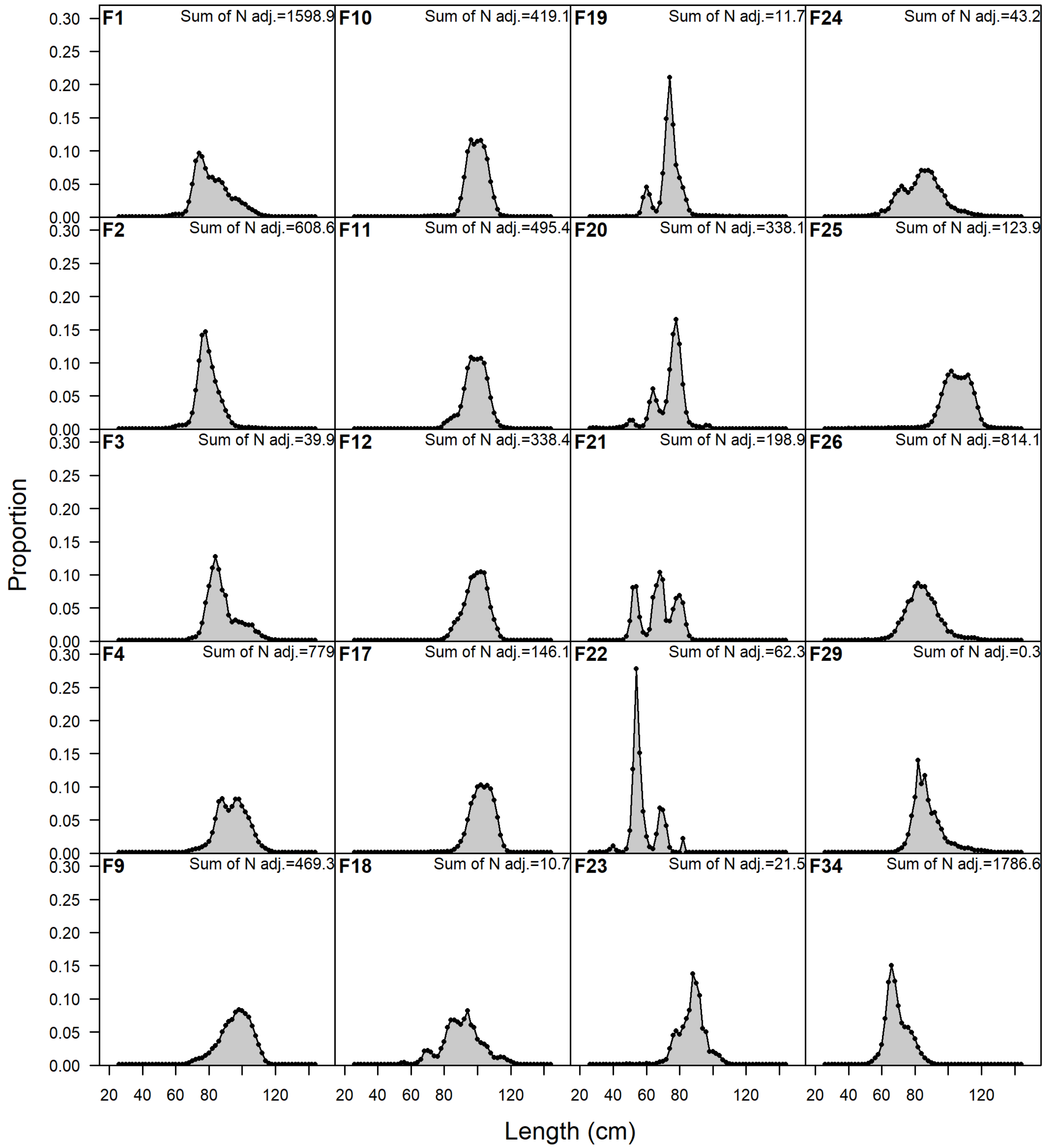


**Figure 11.10**: Aggregated size composition data fitted in the base case model for the 2026 north Pacific albacore stock assessment. Sum of N adj indicate the total sample size of the size composition data for each fishery after data reweighting.

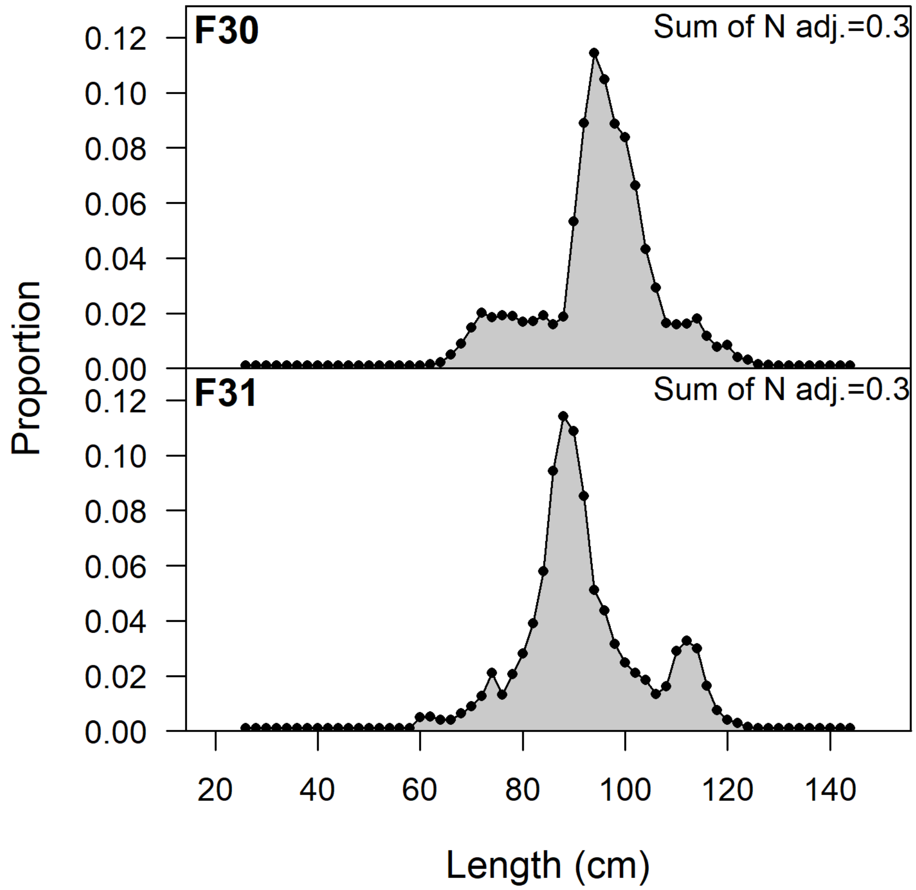


**Figure 11.11**: Aggregated size composition data fitted in the base case model for the 2026 north Pacific albacore stock assessment. Sum of N adj indicate the total sample size of the size composition data for each fishery after data reweighting.

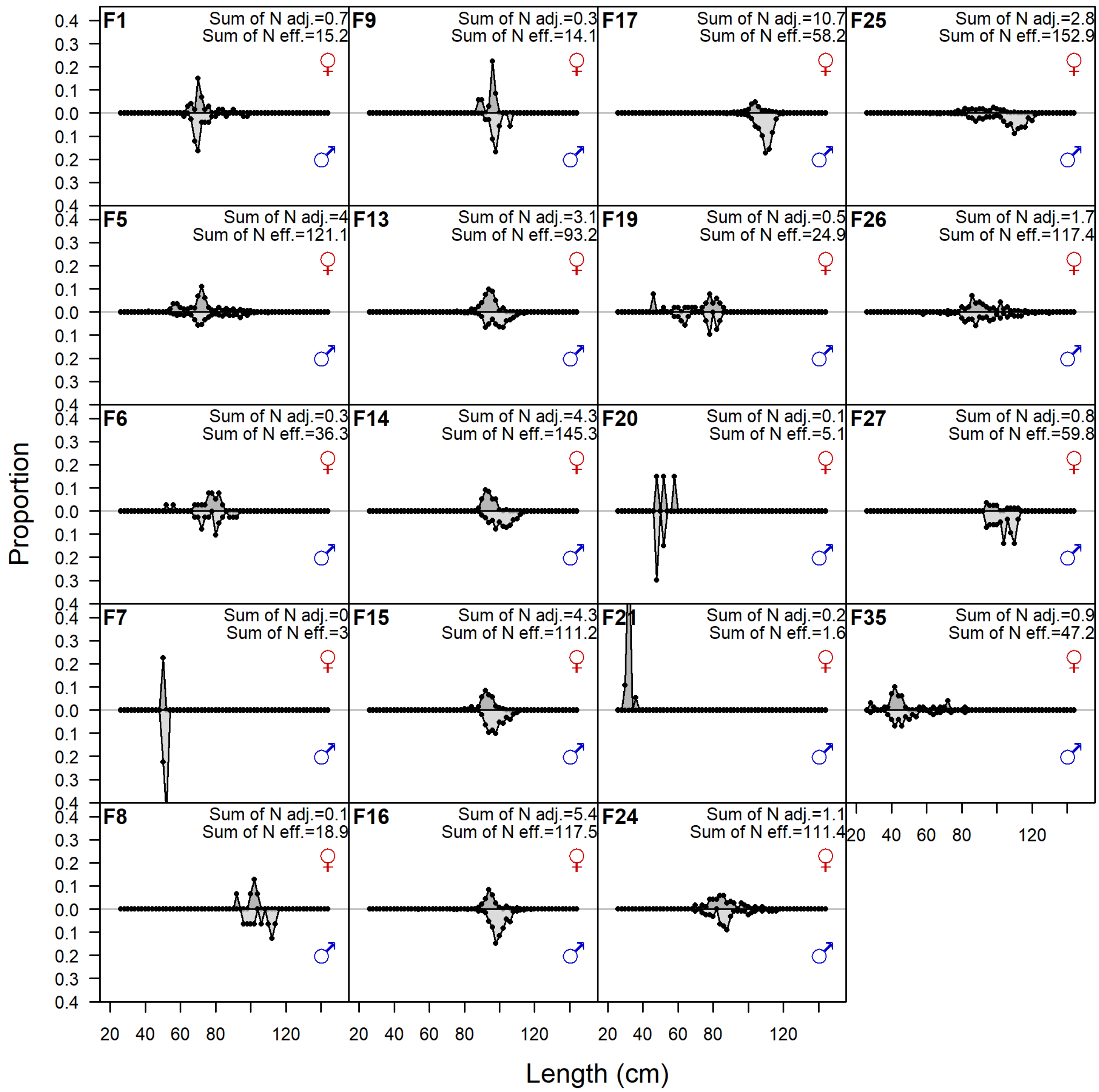


**Figure 11.12**: Aggregated sex-specific size composition data that were available but were not fitted in the base case model for the 2026 north Pacific albacore stock assessment.

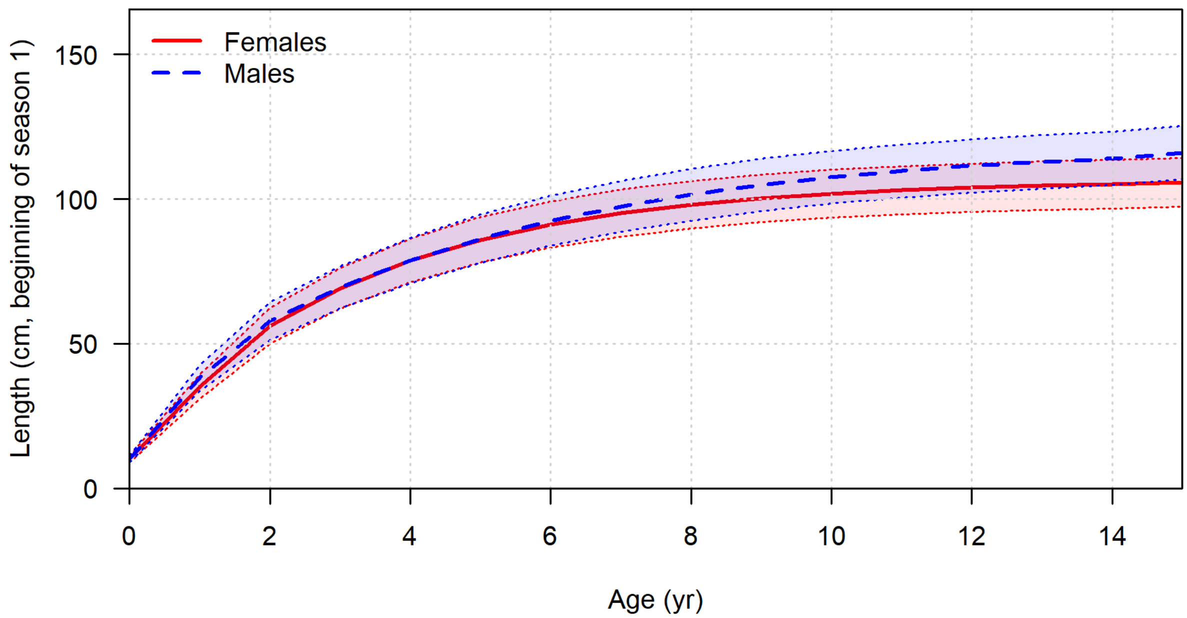


**Figure 11.13**: Growth model of north Pacific albacore used in the 2026 assessment. Dashed lines indicate 95% confidence intervals. Based on sex-specific growth model by Xu et al. (2014). See Table 10.4 for detailed parameters.

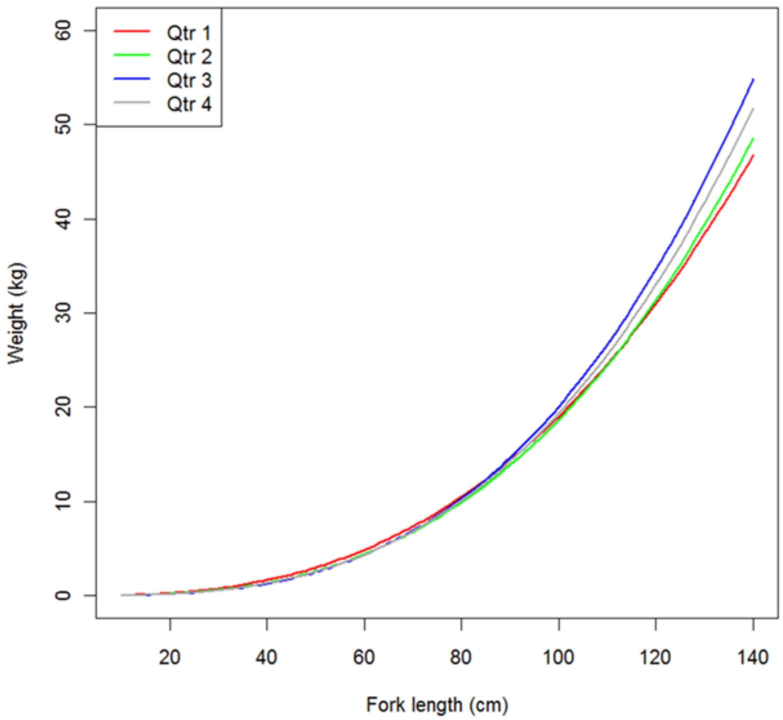


**Figure 11.14**: Seasonal weight-at-length relationships of north Pacific albacore used in the 2026 assessment. Based on Watanabe et al. (2006). Male and female weight-at-length relationships were assumed to be identical. See Table 10.4 for detailed parameters.

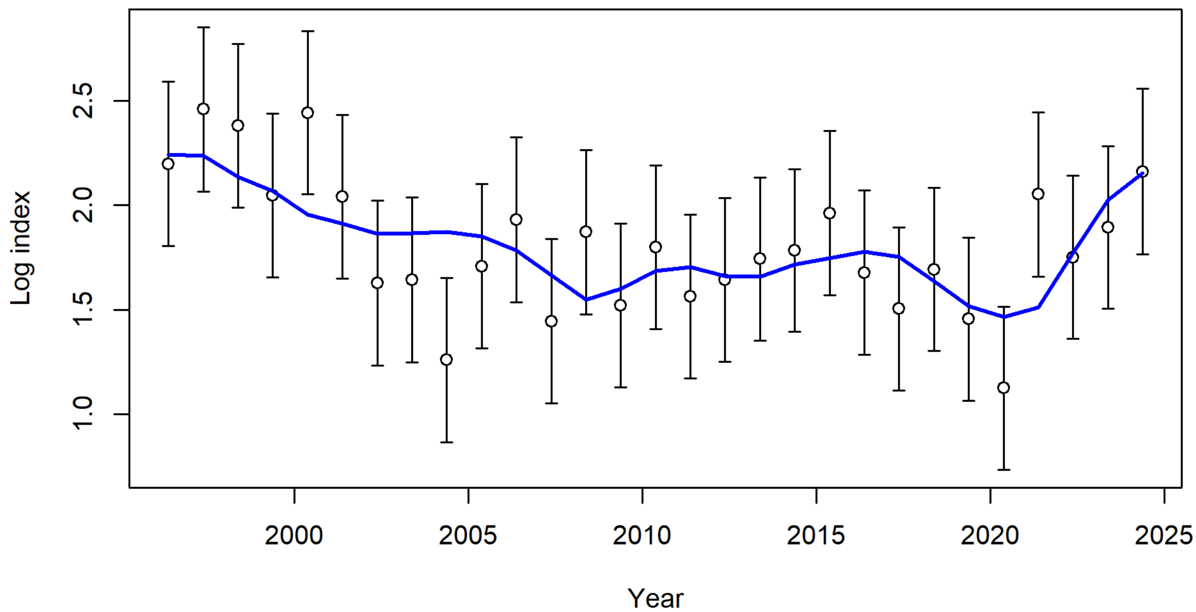


**Figure 11.15**: Log-scale observed (open circles) and predicted (blue line) relative abundance from the F10 adult abundance index in the 2026 base case model. Error bars show the 95% confidence intervals

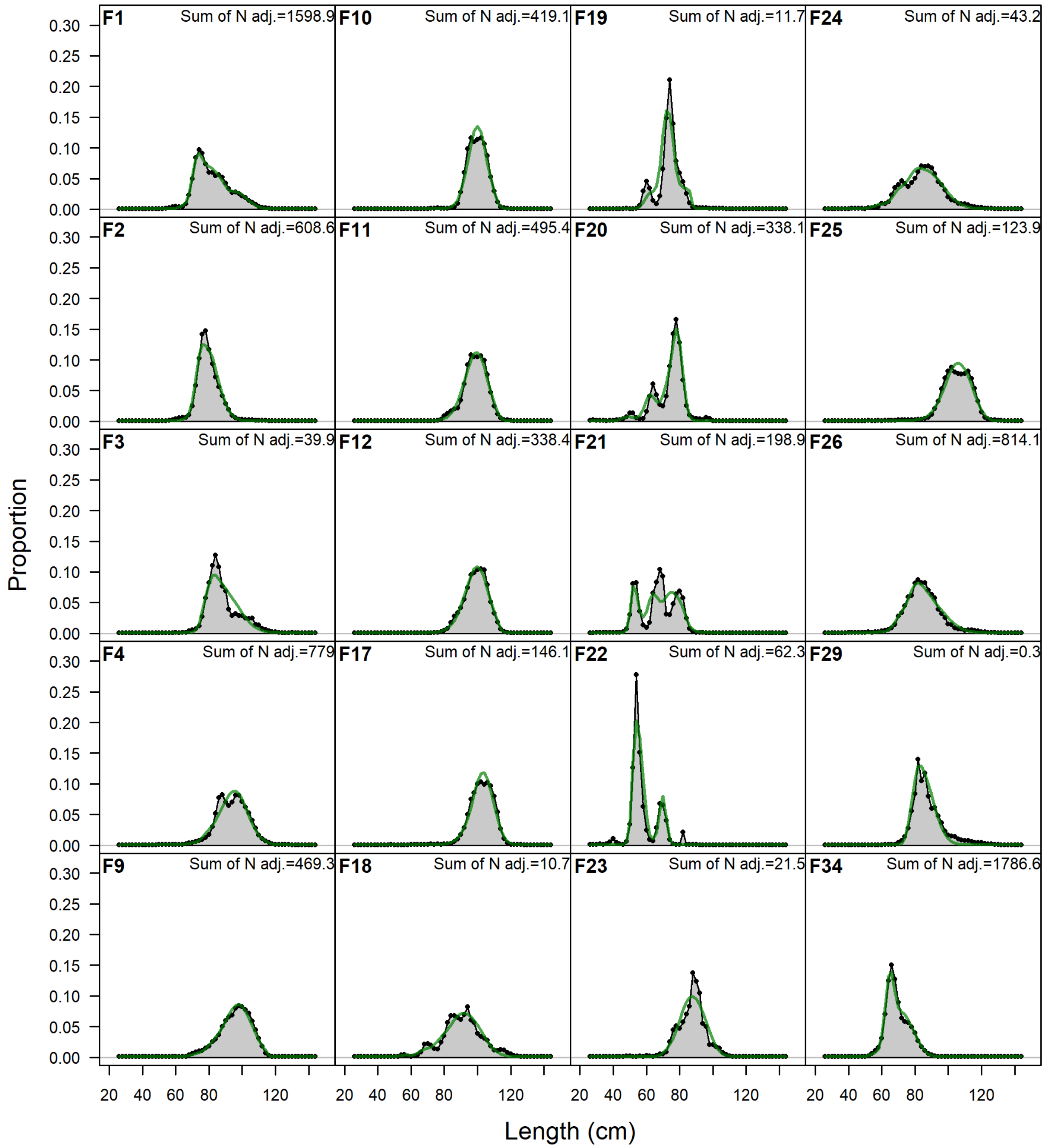


**Figure 11.16**: Observed (grey) and model predicted (green line) aggregated size compositions for the fleets in the 2026 base case model. Only fleets with fitted size compositions are shown. See Table 10.1 for a description of the fleets.

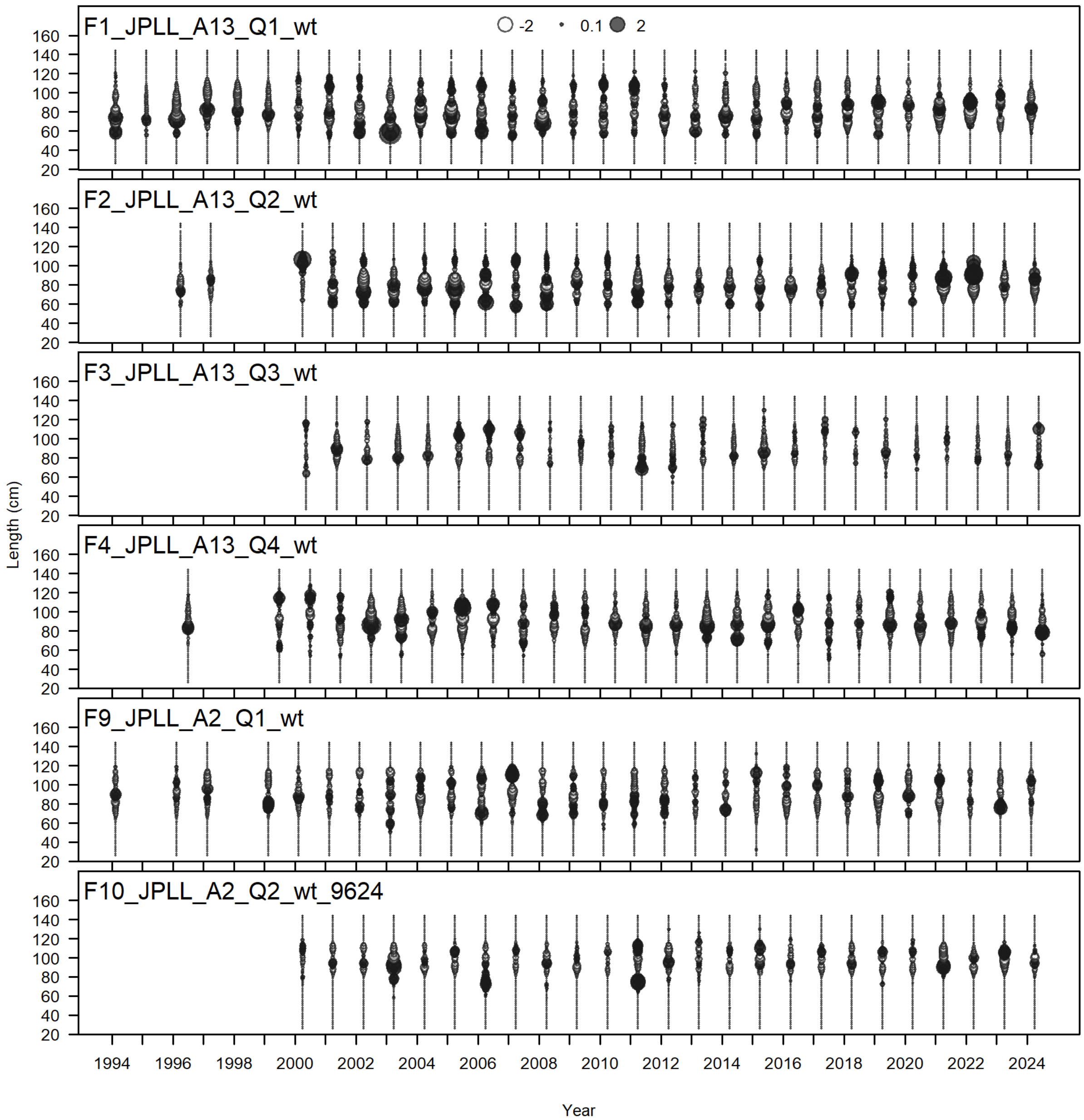


**Figure 11.17**: Pearson residuals of model fit to size composition data from fisheries in the 2026 base case model. Filled and open circles represent observations (i.e., proportions at size) that are larger and smaller than model predictions, respectively. Area of the circle is proportional to absolute values of residuals.

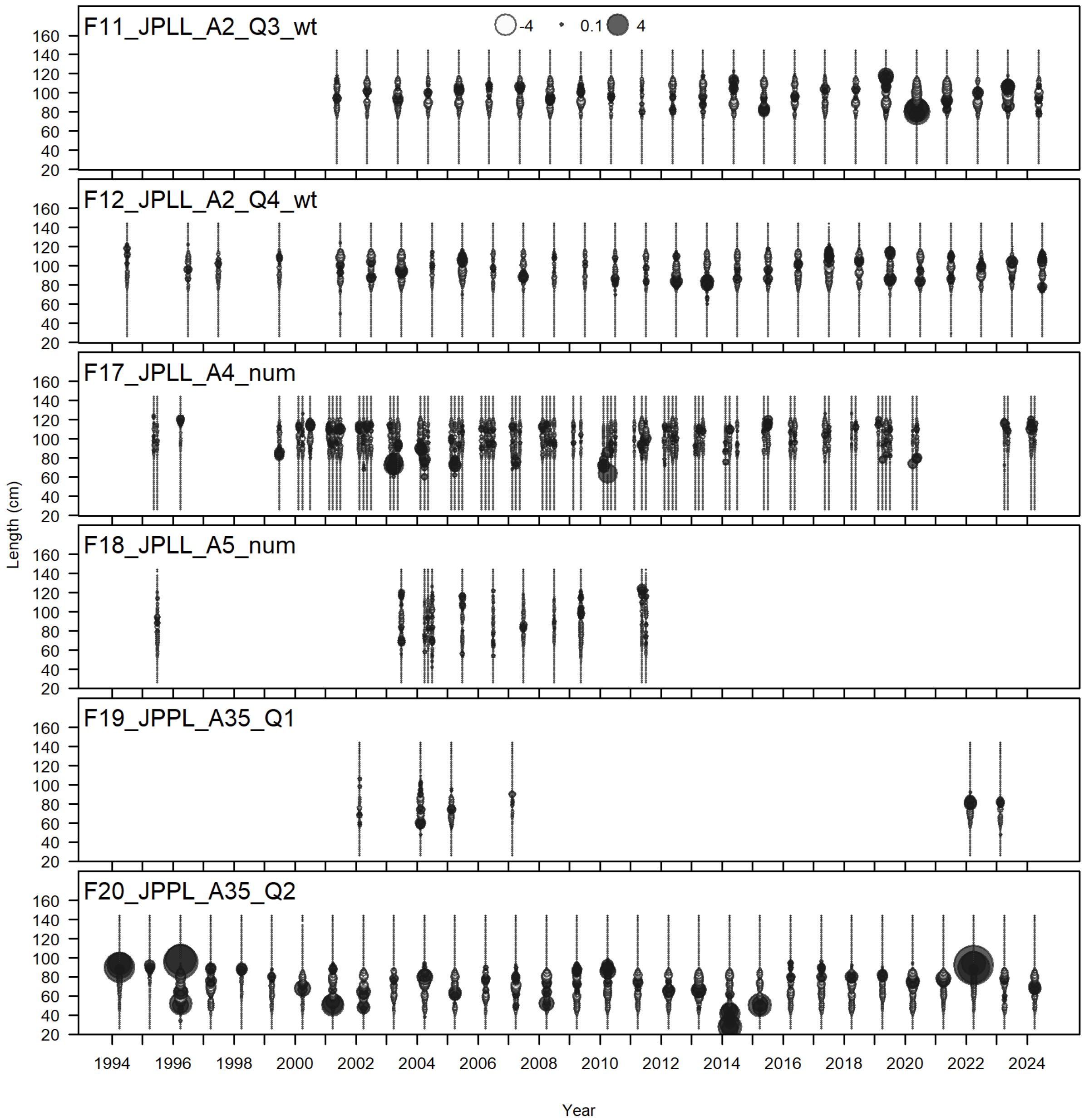


**Figure 11.18**: Pearson residuals of model fit to size composition data from fisheries in the 2026 base case model. Filled and open circles represent observations (i.e., proportions at size) that are larger and smaller than model predictions, respectively. Area of the circle is proportional to absolute values of residuals.

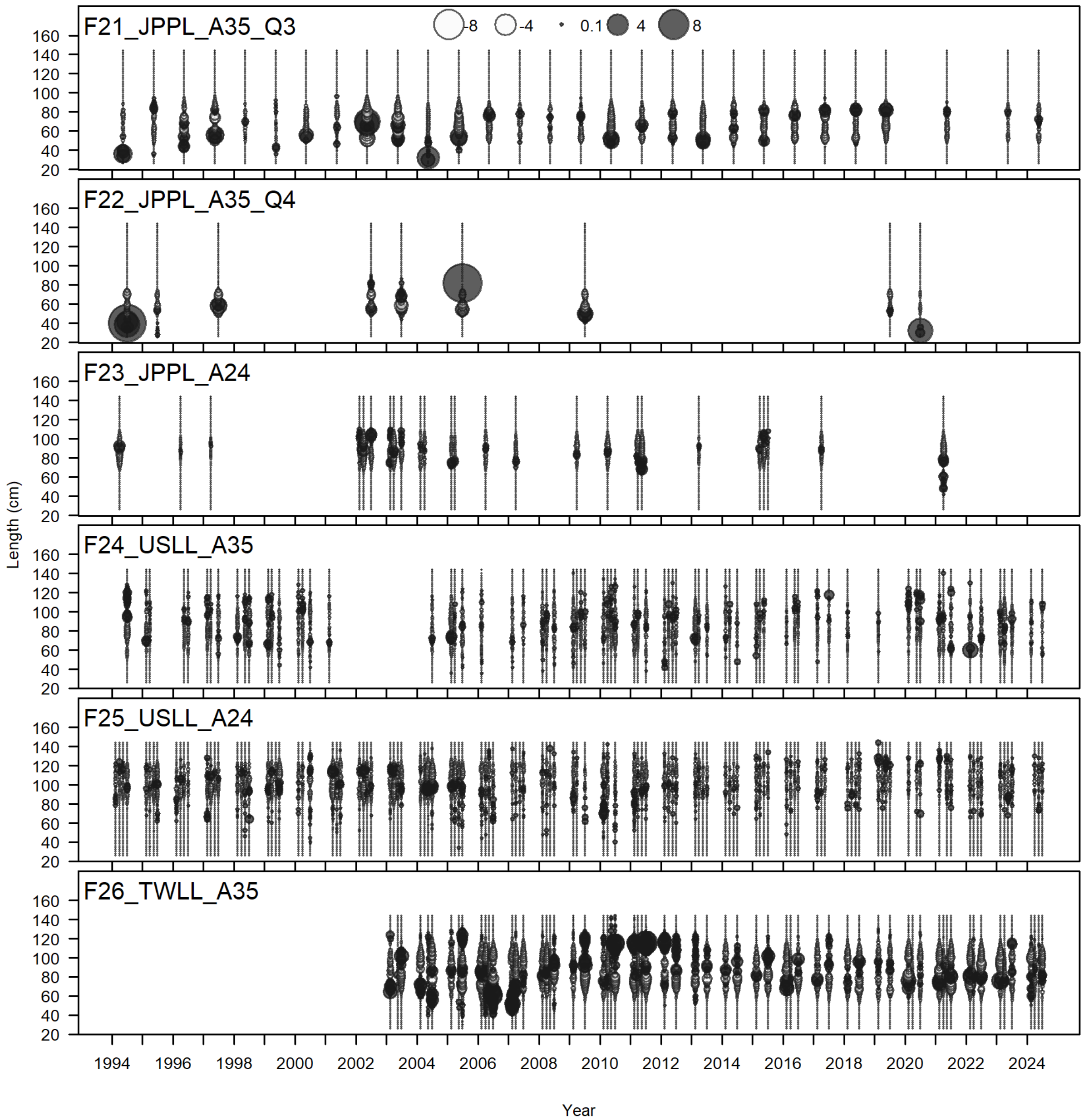


**Figure 11.19**: Pearson residuals of model fit to size composition data from fisheries in the 2026 base case model. Filled and open circles represent observations (i.e., proportions at size) that are larger and smaller than model predictions, respectively. Area of the circle is proportional to absolute values of residuals.

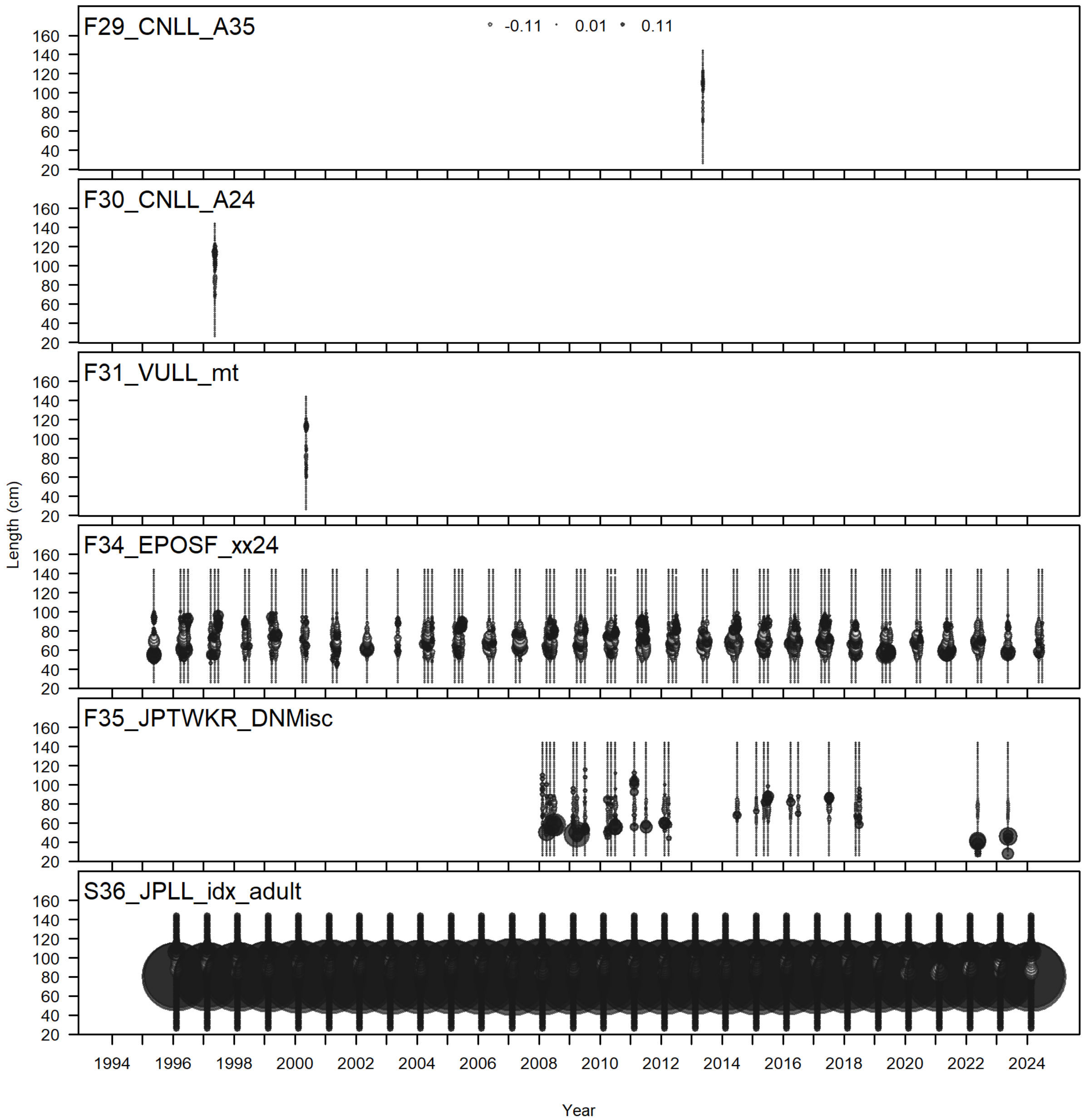


**Figure 11.20**: Pearson residuals of model fit to size composition data from fisheries in the 2026 base case model. Filled and open circles represent observations (i.e., proportions at size) that are larger and smaller than model predictions, respectively. Area of the circle is proportional to absolute values of residuals.

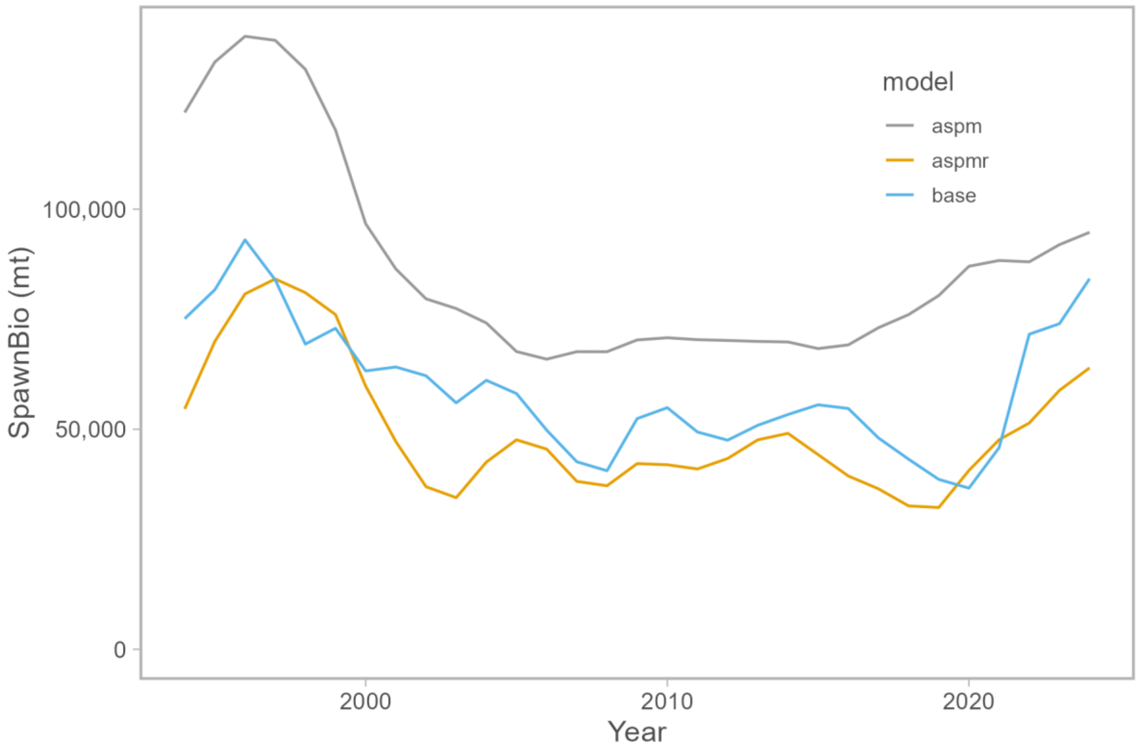


**Figure 11.21**: Estimated female spawning stock biomass from the base case (blue), ASPM (gray), and ASPM-R (orange) models.

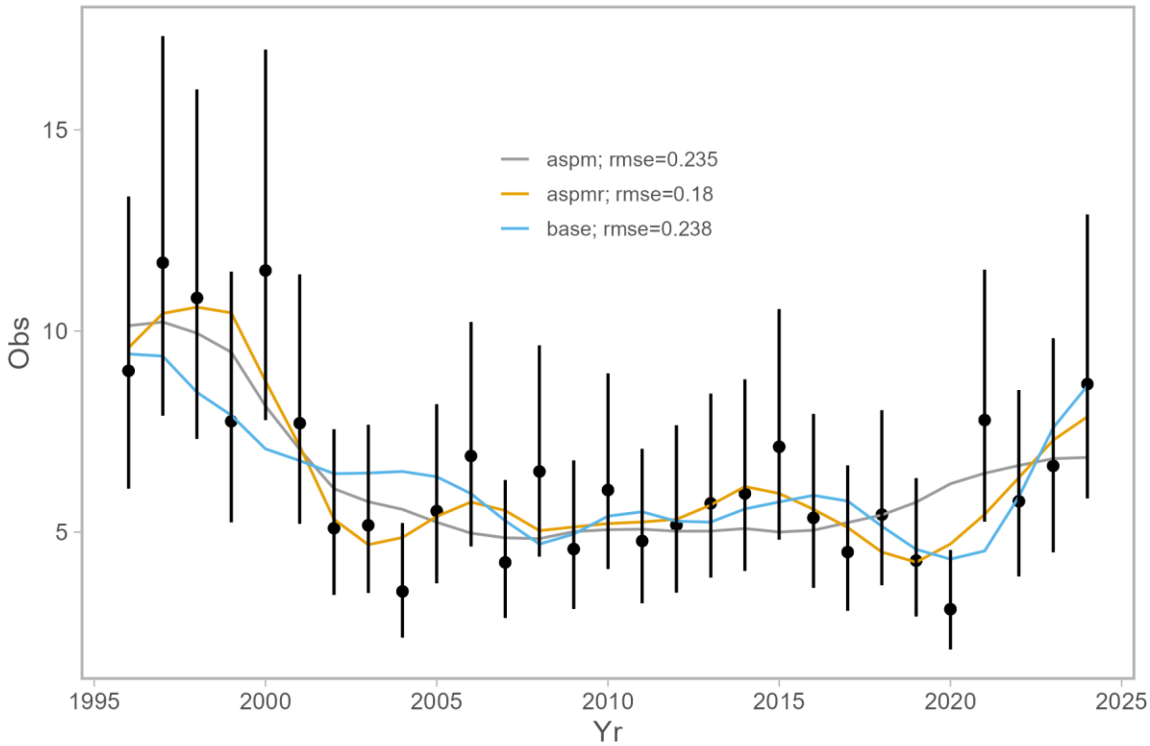


**Figure 11.22**: Fits to the F10 index of abundance from the base case (blue), ASPM (gray), and ASPM-R (orange) models with RMSE.

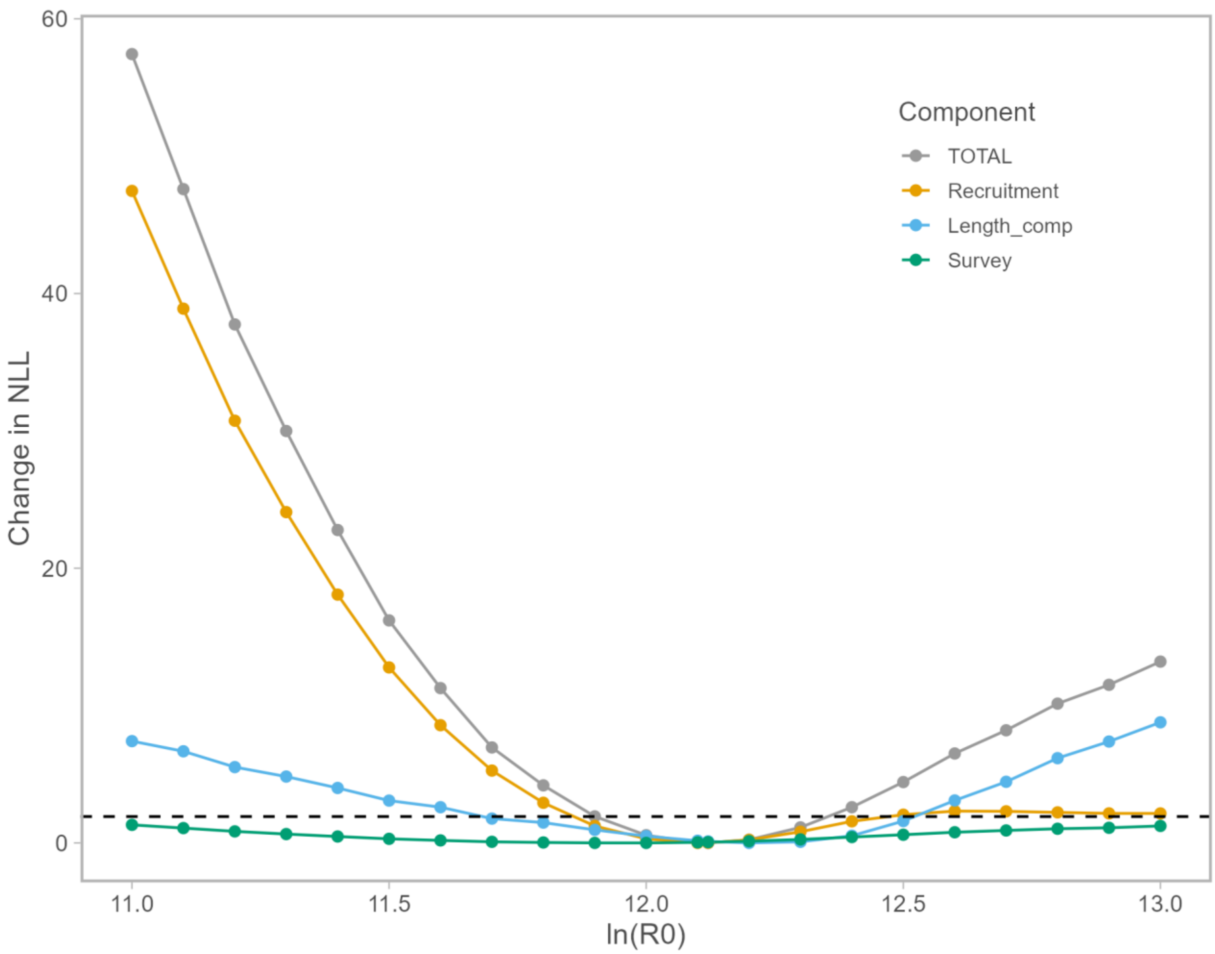


**Figure 11.23**: Likelihood profiles across fixed values of $R_0$. Likelihood components shown are total likelihood (gray), recruitment (orange), length composition data (blue), and survey index of abundance (green). Values within 1.92 units of the MLE (dashed horizontal line) are within the 95% confidence interval. The base model estimated $R_0$ value was 12.120.

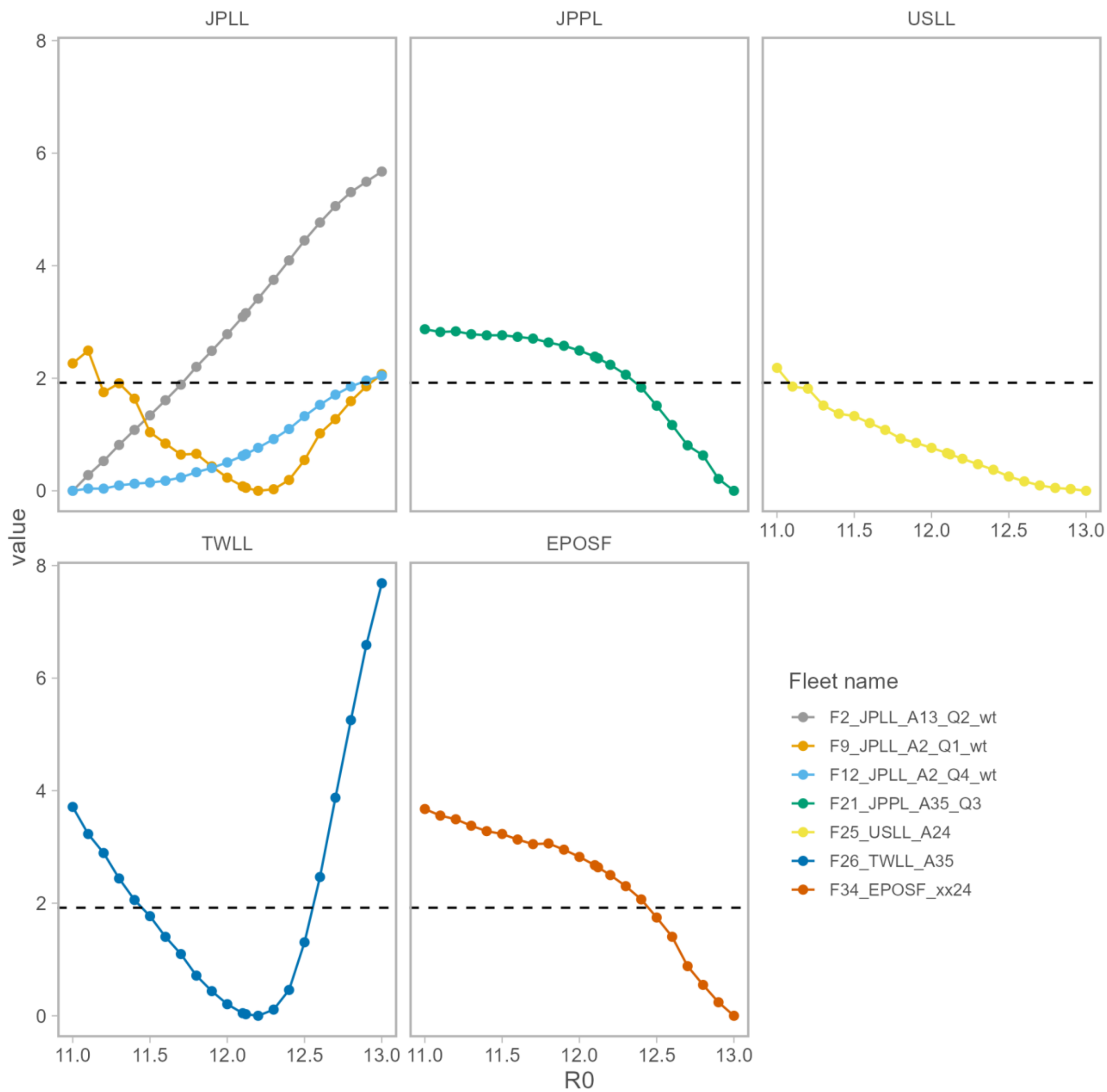


**Figure 11.24**: Likelihood profiles across fixed values of $R_0$ for the statistically significant length likelihood components. Panels are arranged by fishery category and colors indicate the specific fleet numbers. Values within 1.92 units of the MLE (dashed horizontal line) are within the 95% confidence interval. The base model estimated $R_0$ value was 12.120.

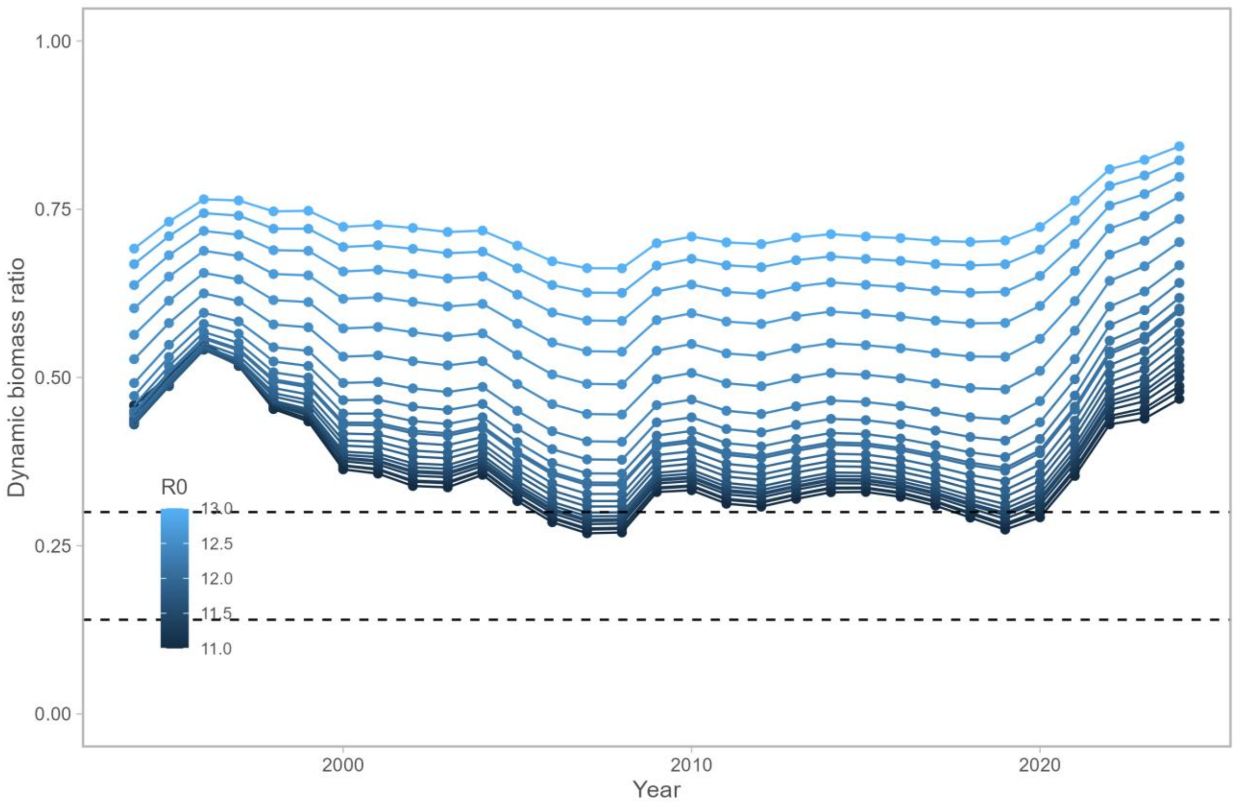


**Figure 11.25**: Estimated dynamic biomass ratios (i.e., ratios of female spawning stock biomass (SSB) relative to dynamic, unfished SSB) of the base case model (black line) and models with virgin recruitment $ln(R_0)$ fixed at various values. Horizontal lines indicate the threshold (dashed black line; $30\%SSB_{current,F=0}$) and limit (solid red line; $14\%SSB_{current,F=0}$) reference points.

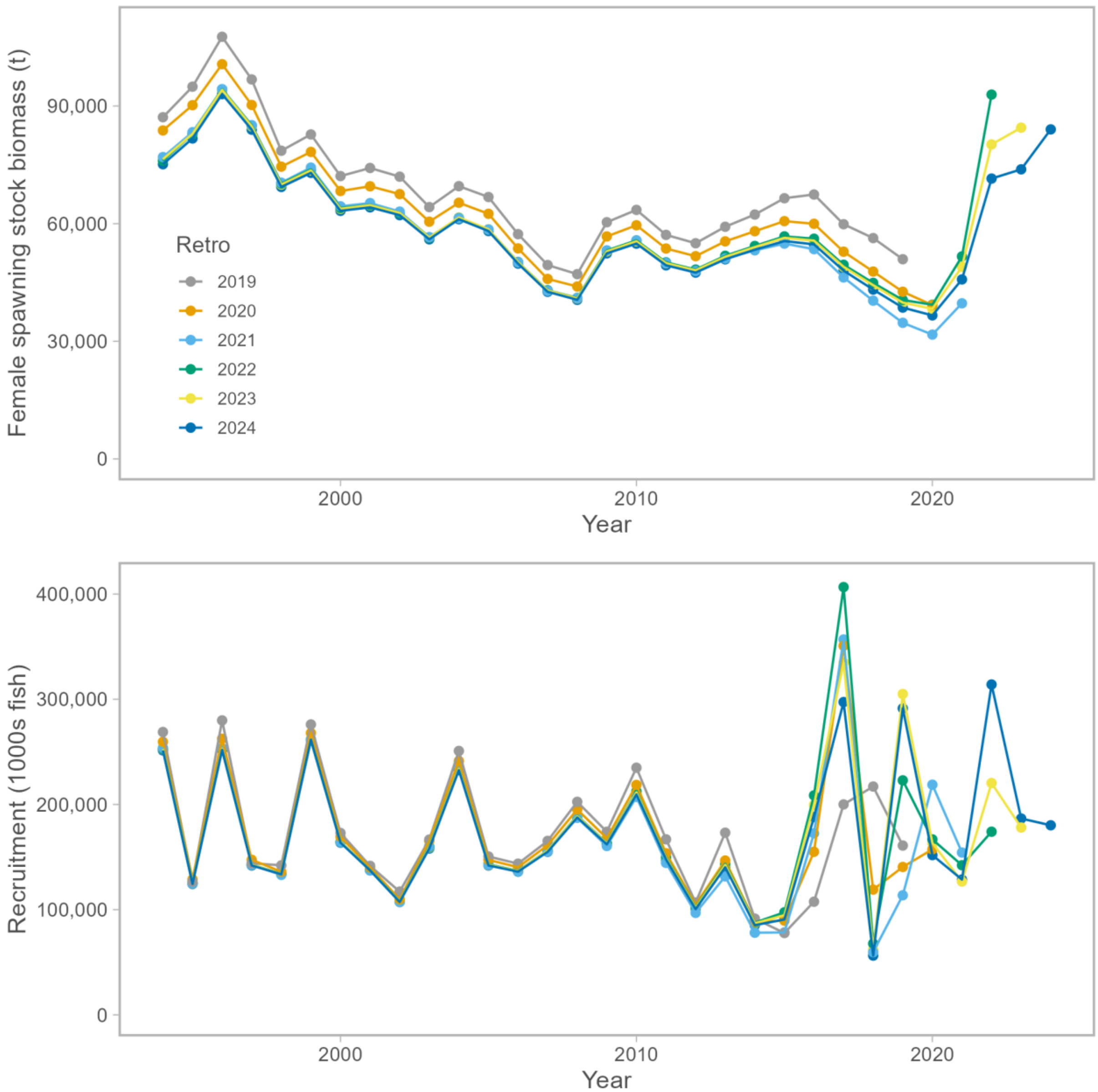


**Figure 11.26**: Estimated female spawning biomass (SSB) (top), and recruitment (bottom) of the base case model and models with one to five terminal years of data removed. Legend indicates terminal year of the model.

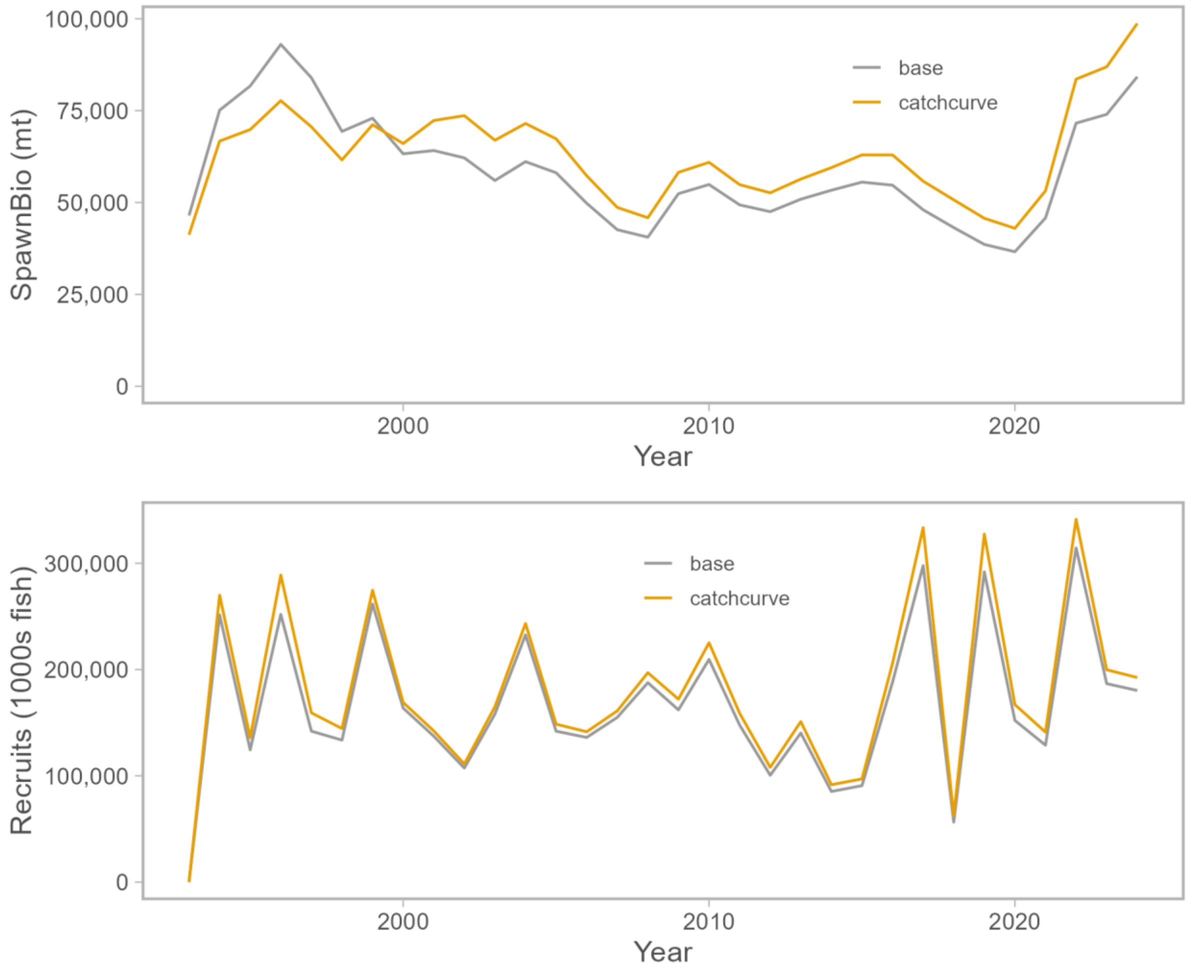


**Figure 11.27**: Estimated female spawning biomass (top) and recruitment (bottom) of the base case model (gray) and catch curve analysis (orange).

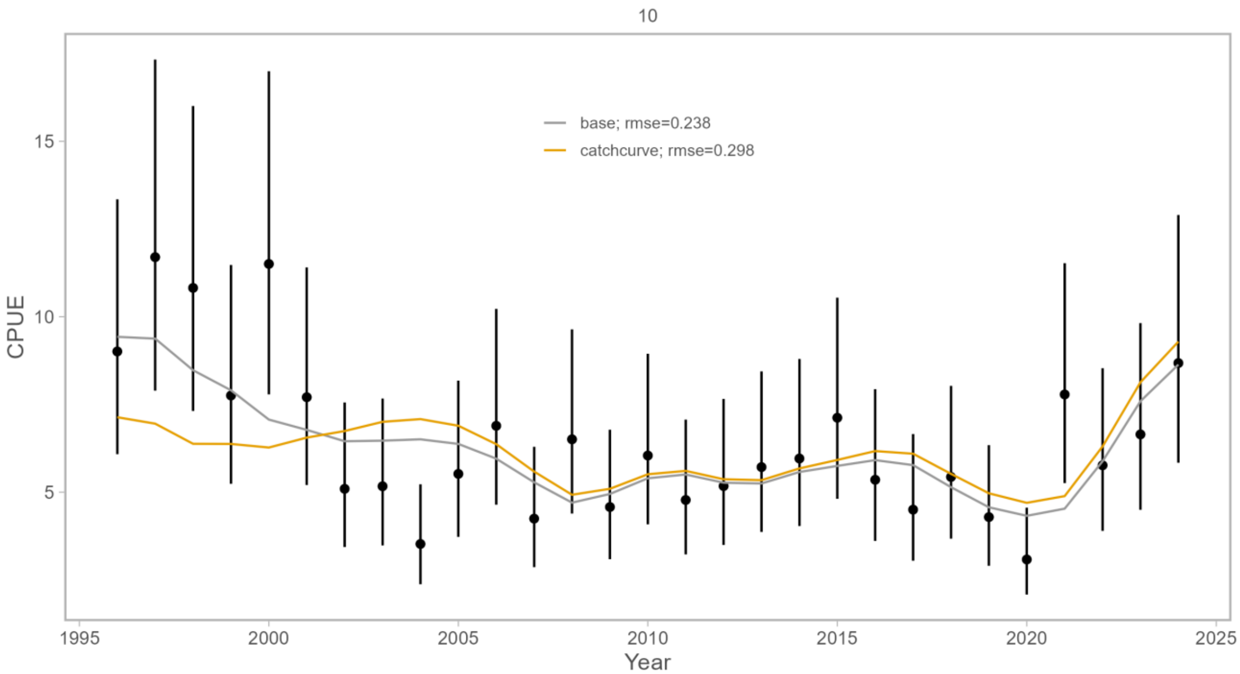


**Figure 11.28**: Fits to the F10 index of abundance from the base case model (gray) and catch curve analysis (orange).

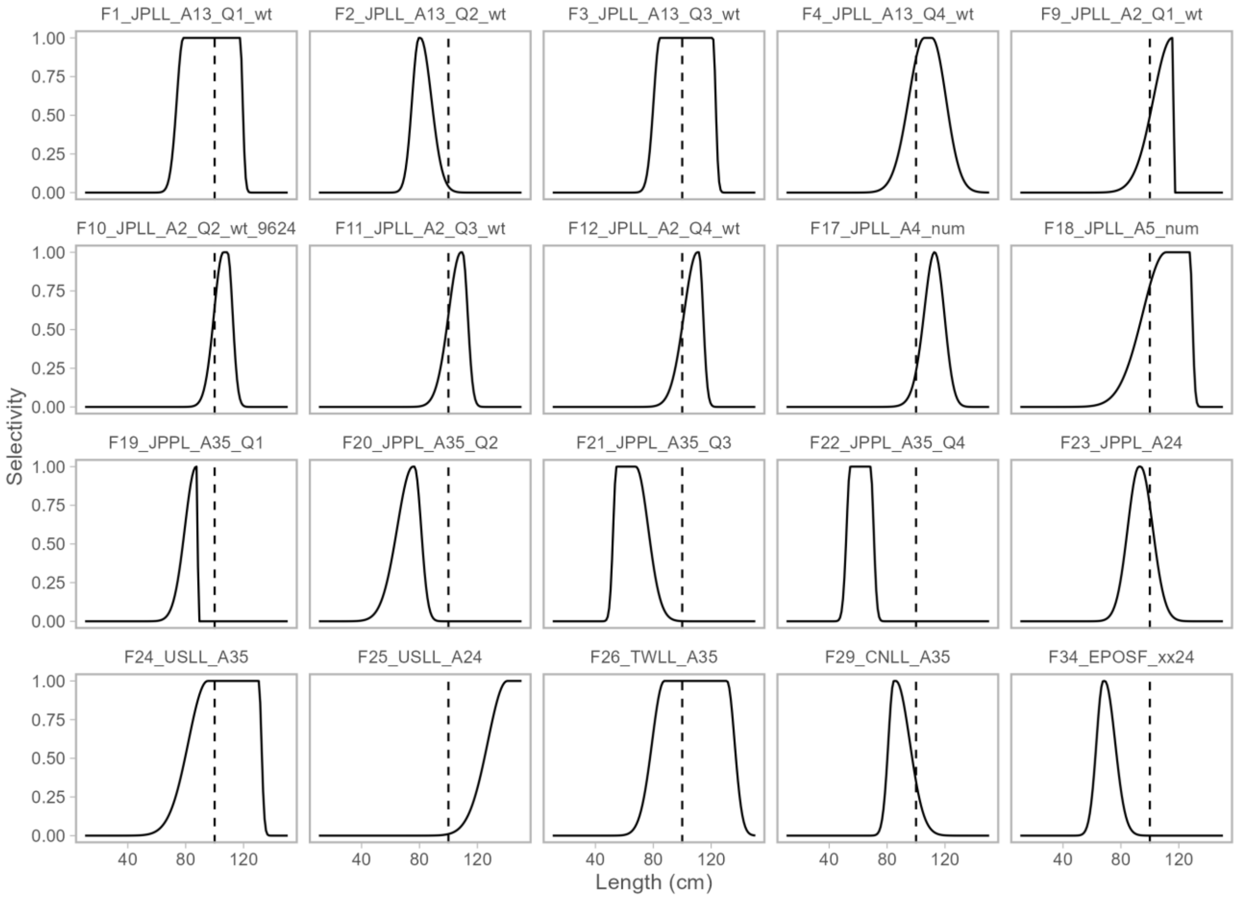


**Figure 11.29**: Estimated length-based selectivity, arranged by fleet. Male selectivity is identical to female selectivity in the base case model. Only fisheries with size composition data fitted in the base case model are shown. Vertical dashed line is at 100cm to help visualize differences between the fleet selectivities.

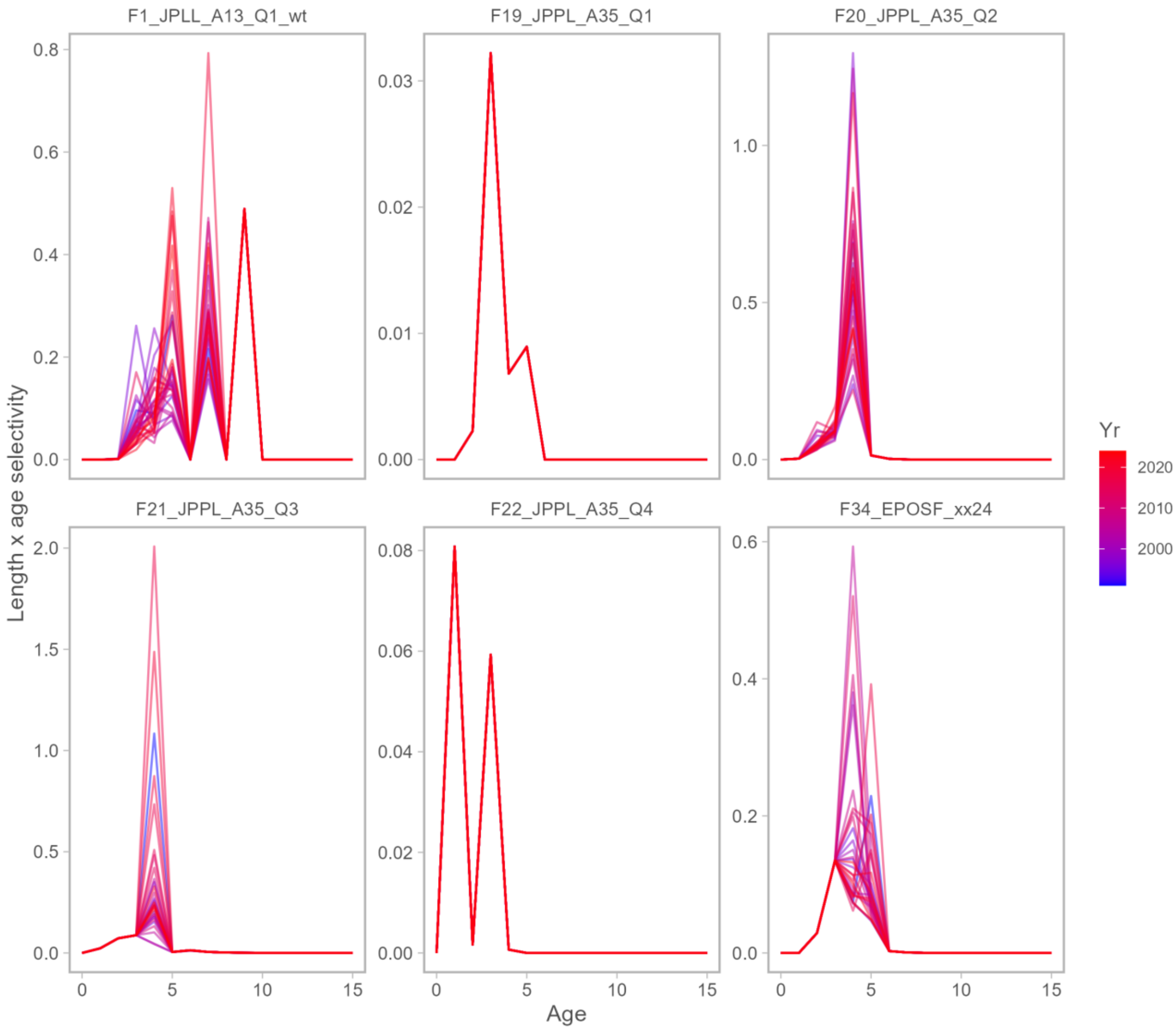


**Figure 11.30**: Estimated age multiplied by length selectivity, arranged by fleet. Fleets shown are those that had both age and length selectivity estimated. Male selectivity is identical to female selectivity in the base case model. Only fisheries with size composition data fitted in the base case model are shown.

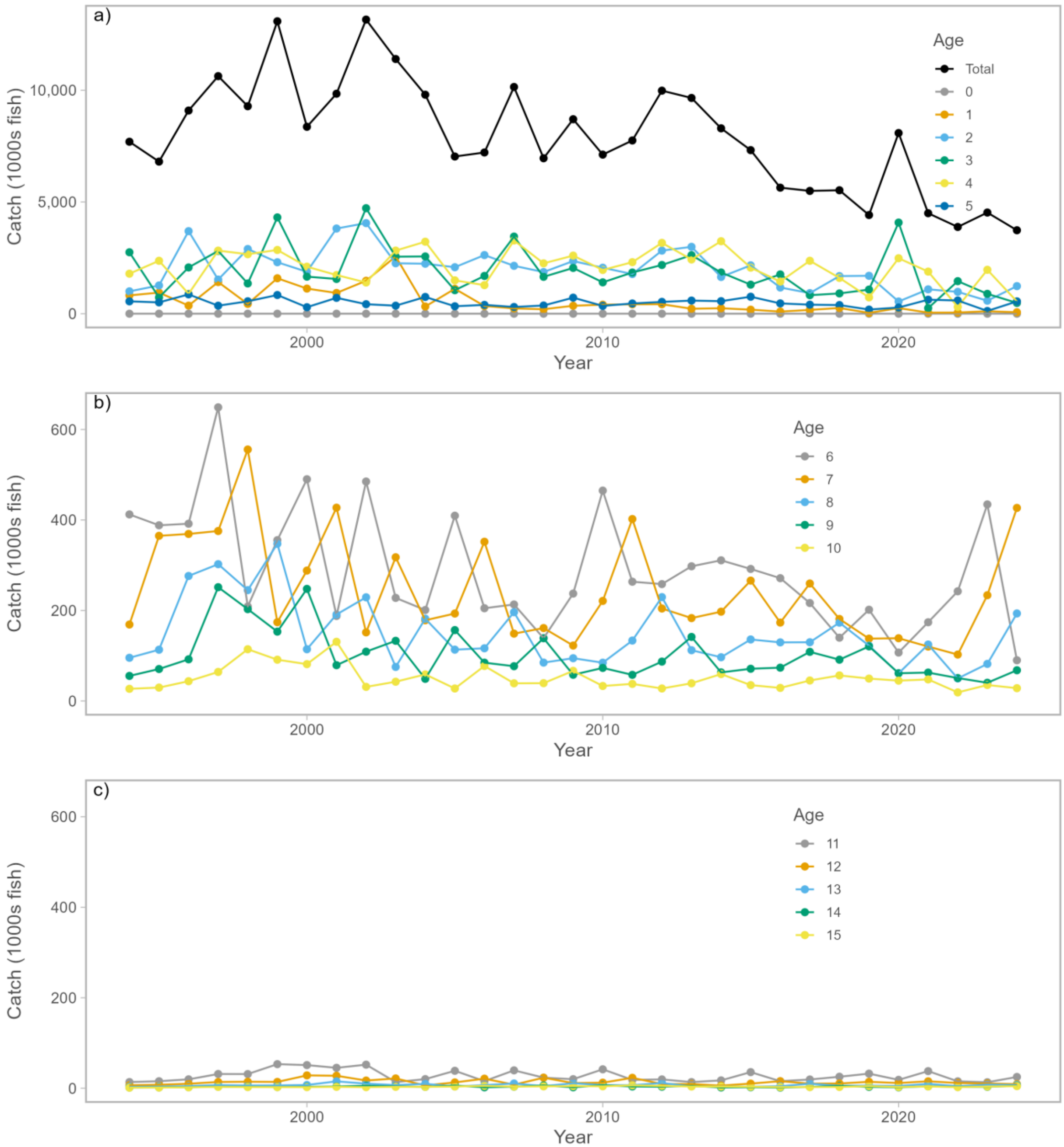


**Figure 11.31**: Historical catch at age of north Pacific albacore estimated by the 2026 base case model. Panels are arranged for the total catch and ages 0-5 (top), 6-10 (middle), and 11-15 (bottom). Note the difference in y-axis scale between the top panel and middle and bottom panels.

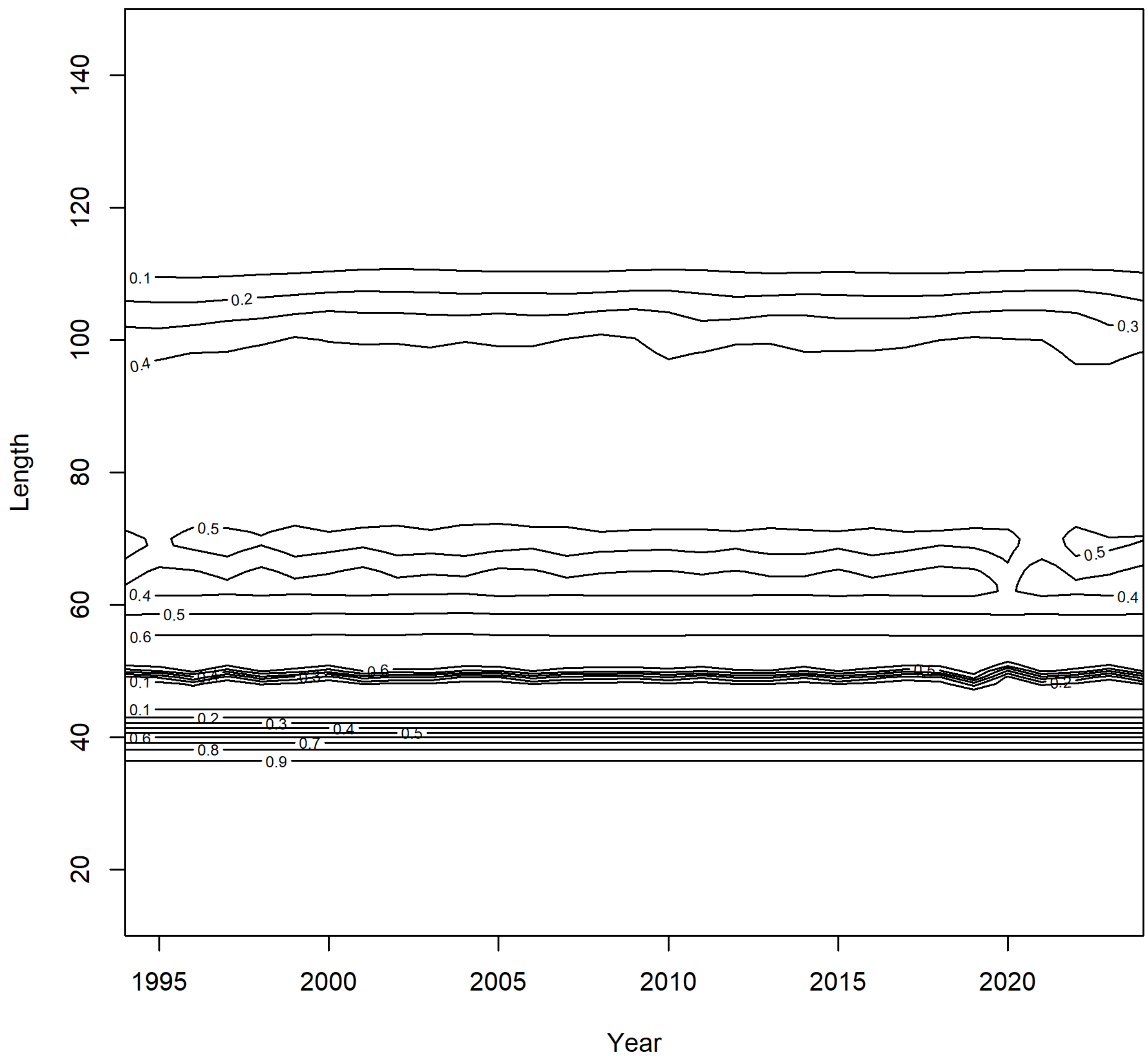


**Figure 11.32**: Estimated fraction of females in the population by age.

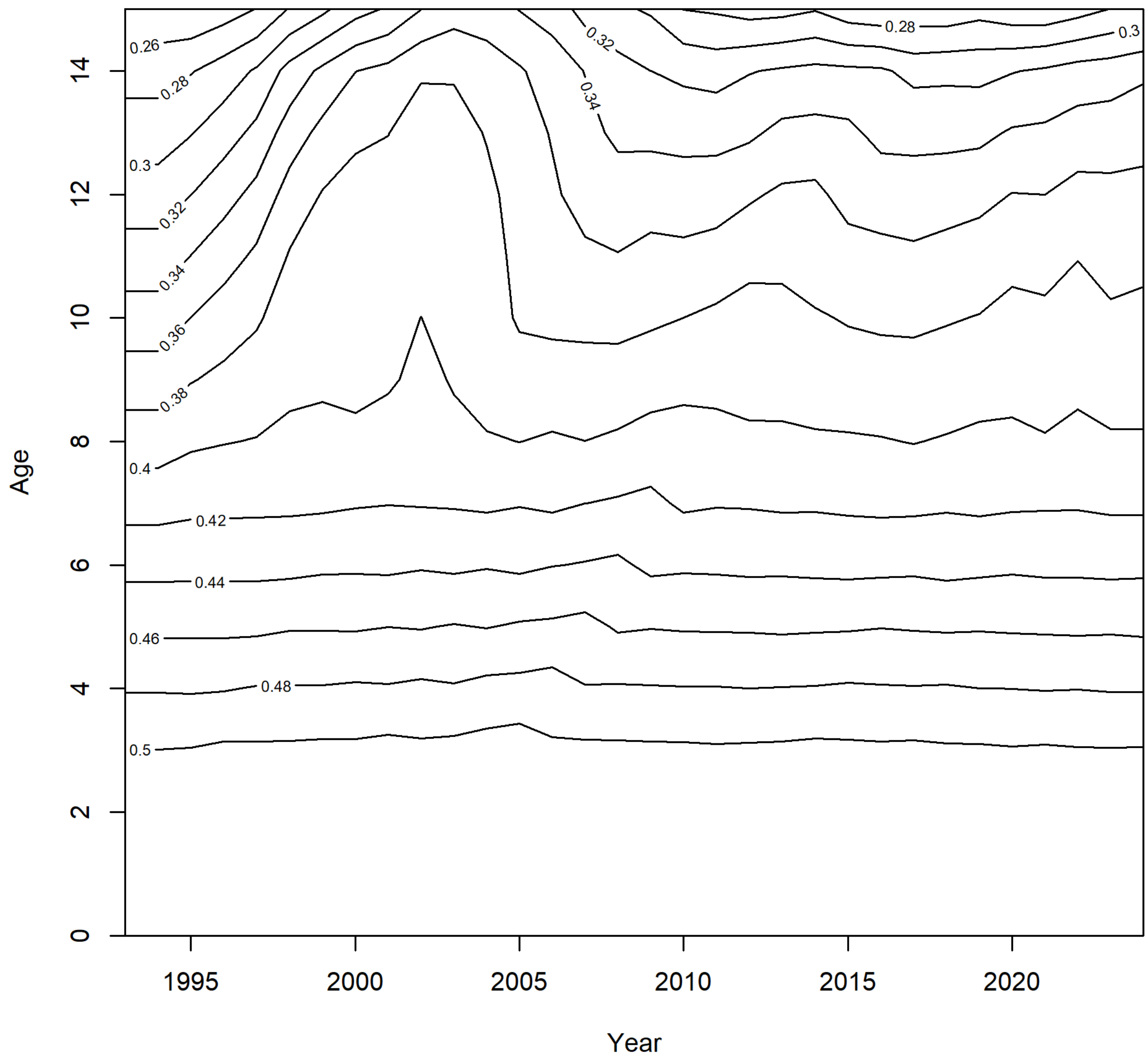


**Figure 11.33**: Estimated fraction of females in the population by fork length (cm).

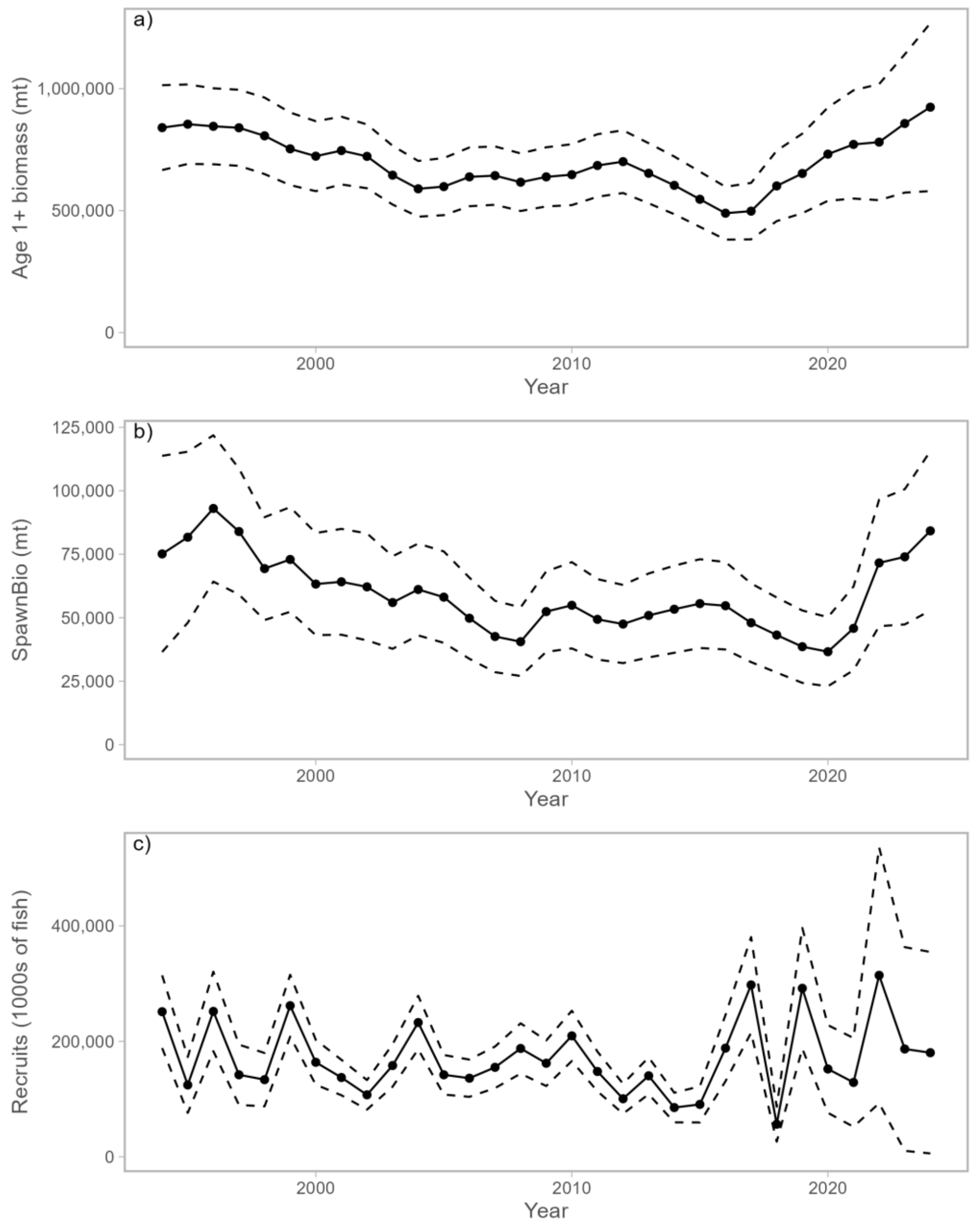


**Figure 11.34**: Maximum likelihood estimates of (a) age-1+ biomass, (b) female spawning biomass (SSB), and (c) age-0 recruitment of north Pacific albacore tuna (*Thunnus alalunga*). Dashed lines indicate 95% confidence intervals.

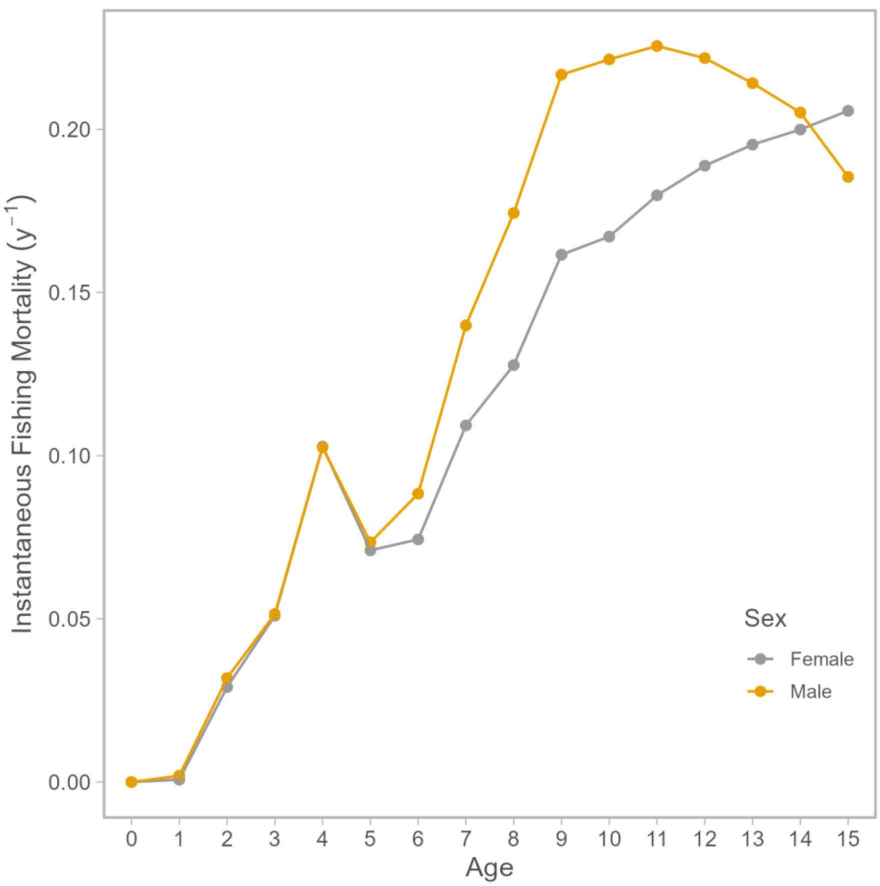


**Figure 11.35**: Estimated sex-specific instantaneous fishing mortality at age (F-at-age) for the 2026 base case model, averaged across 2021-2023.

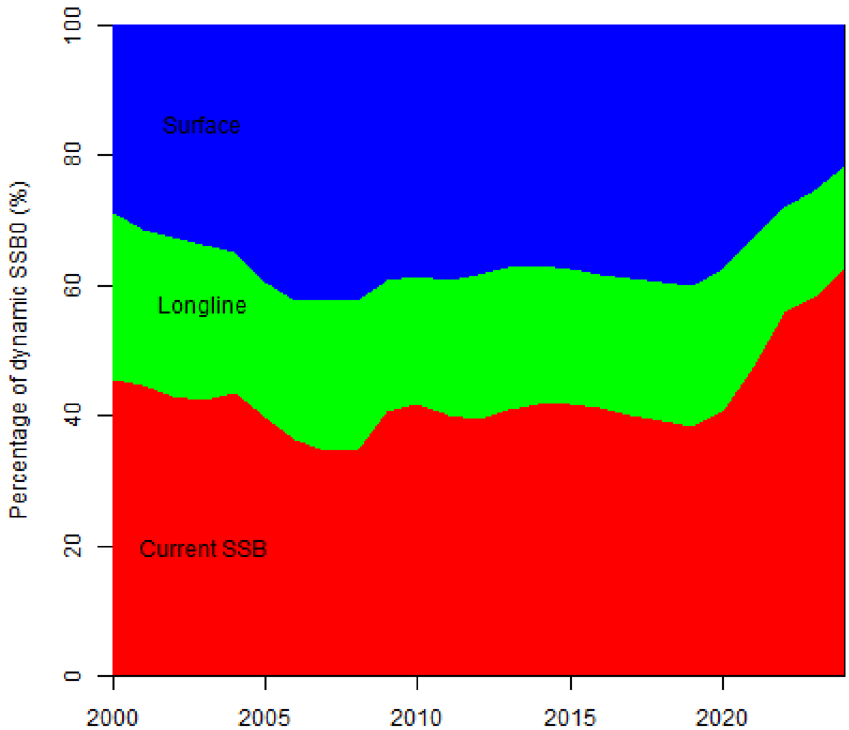


**Figure 11.36**: Fishery impact analysis on north Pacific albacore showing female spawning biomass (SSB; red) estimated by the 2026 base case model as a percentage of dynamic, unfished female SSB ($SSB_{current,F=0}$). Colored areas show the relative proportion of fishing impact attributed to longline (green) and surface (blue) fisheries (primarily troll and pole-and-line gear, but including all other gears except longline).

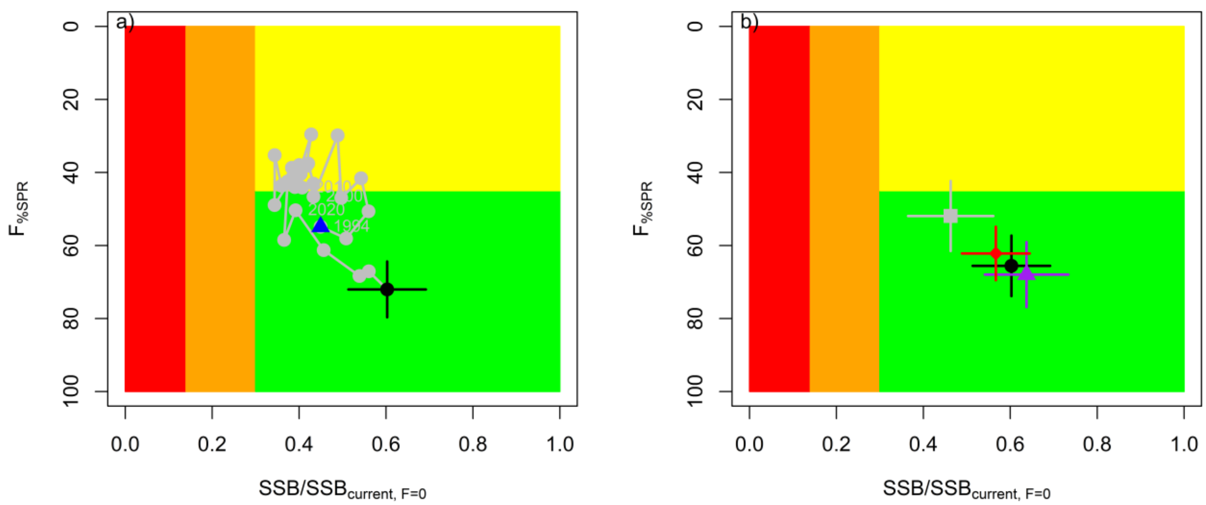


**Figure 11.37**: (a) Stock status phase plot showing the status of the north Pacific albacore (*Thunnus alalunga*) stock relative to the biomass-based threshold ($30\%SSB_{current,F=0}$) and limit ($14\%SSB_{current,F=0}$) reference points, and fishing intensity-based target reference point (F45%SPR) over the modeling period (1994 – 2024). Blue triangle indicates the start year (1994) and black circle with 95% confidence intervals indicates the terminal year (2024). (B) Stock status plot showing current stock status and 95% confidence intervals of the base case model (black circle), a sensitivity run an important sensitivity run of CV = 0.06 for Linf in the growth model (gray), an important sensitivity run with two initial fishing mortality parameters (red), and a model representing an update of the 2023 base case model to 2026 data (purple). Red zones in both panels indicate female SSBs falling below the limit reference point while the orange zones indicate female SSBs between the threshold and limit reference points. Green zones indicate female SSBs above the threshold reference point and fishing intensity levels below the target reference point. Yellow areas indicate female SSBs above the threshold reference point and fishing intensity levels above the target reference point. The Fs in this figure are indicators of fishing intensity based on spawning potential ratio (SPR) and calculated as %SPR. SPR is the ratio of the equilibrium SSB per recruit that would result from the estimated F-at-age relative to that of an unfished population. A higher %SPR indicates lower fishing intensity. Current fishing intensity values and SSB/SSBcurrent,F=0 ratios in (B) were calculated as the average during 2021-2023 (F%SPR, 2021-2023) and 2024 (SSB2024/SSBcurrent, F=0), respectively. The model representing an update of the 2023 base case model is similar to but not identical to the 2023 base case model due to changes in data preparation and model structure.

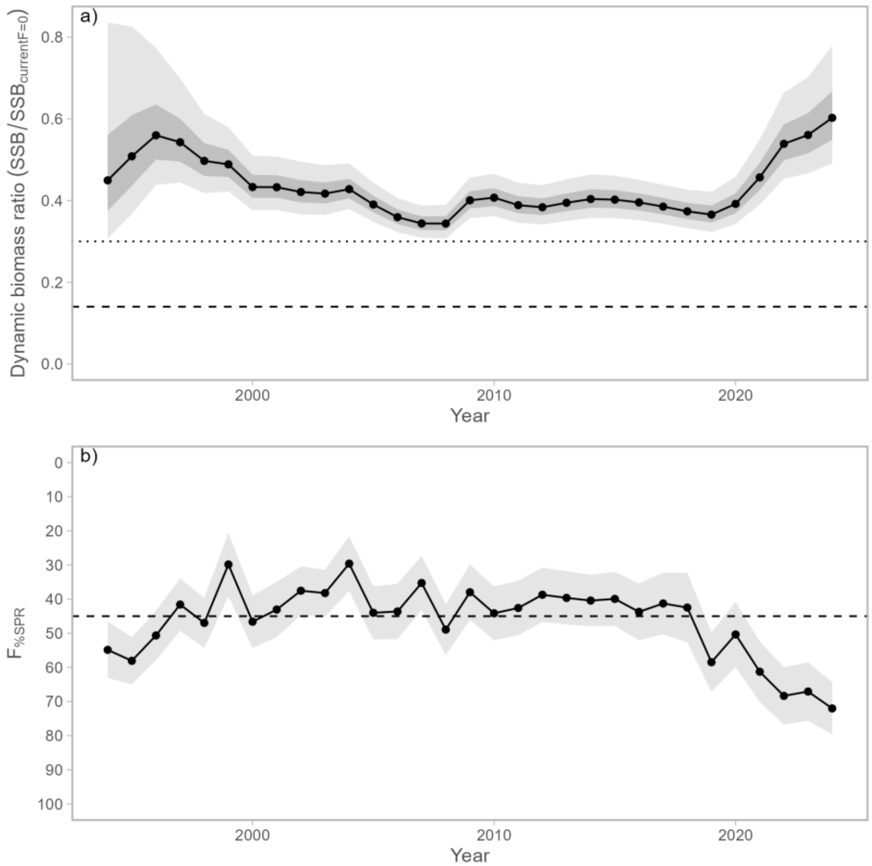


**Figure 11.38**: (A) Estimated dynamic biomass ratio (SSB/SSBcurrent, F=0) of north Pacific albacore relative to biomass-based threshold (30%SSBcurrent, F=0; dotted line) and limit (14%SSBcurrent, F=0; dashed line) reference points over the modeling period (1994 – 2024). 95% confidence intervals are indicated by the lighter gray bands and 60% confidence intervals are indicated by the darker gray bands. (B) Estimated fishing intensity relative to the fishing intensity-based target reference point (F45%SPR) over the modeling period (1994 – 2024). The gray area indicates the 95% confidence intervals. The limit reference point is considered to be breached if the lower bound of the 60% confidence intervals overlaps the limit reference point.

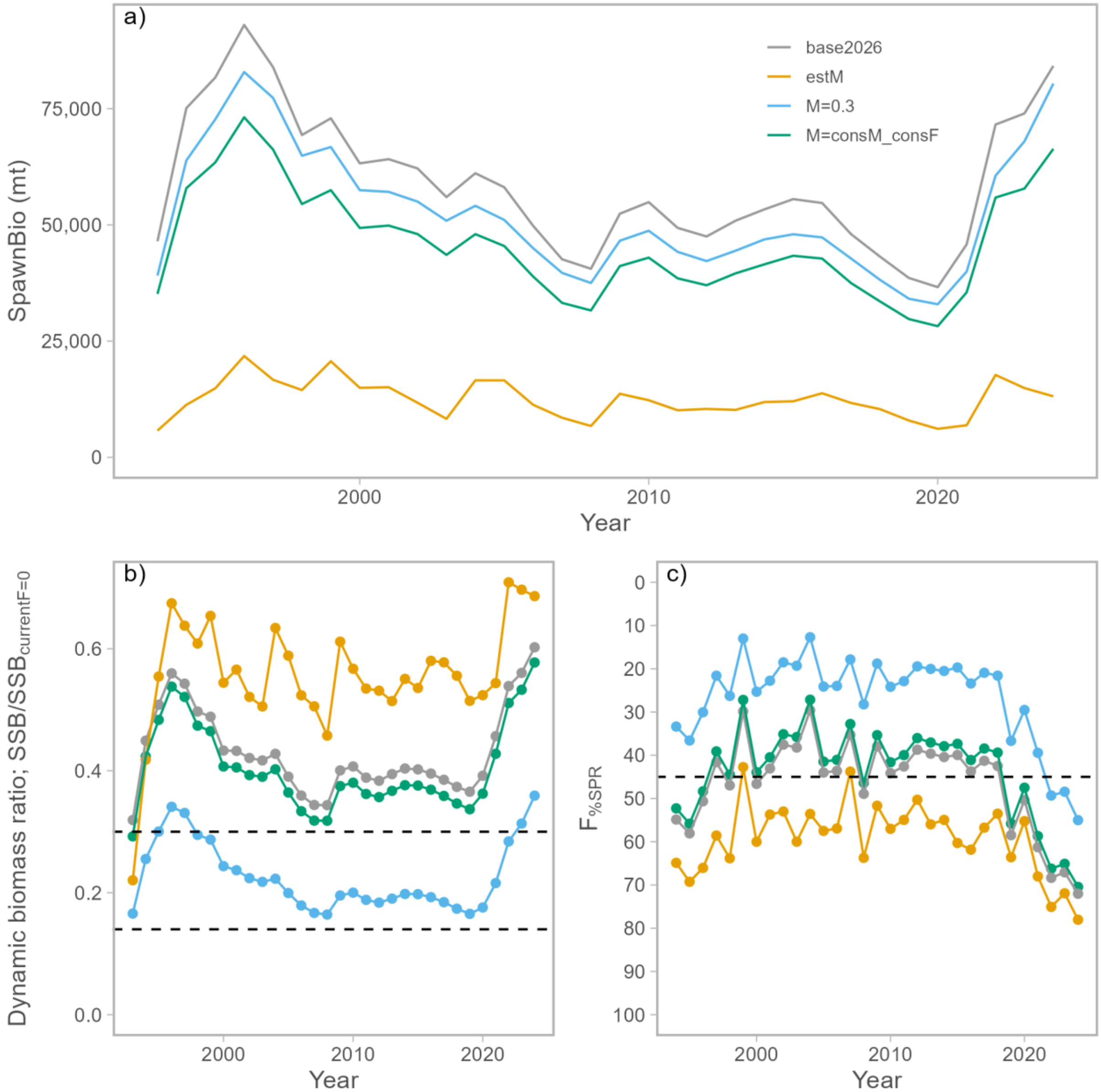


**Figure 11.39**: Estimated female spawning biomass (a), dynamic spawning biomass depletion (b), and fishing intensity ($F_{\%SPR}$; c) for the 2026 base case model (gray), sensitivity run with fixed constant M of 0.3 across sexes and ages (M=0.3; blue), constant M of 0.39 for males and 0.48 for females (M=consM_consF; green), and estimated M with a prior (estM; orange).

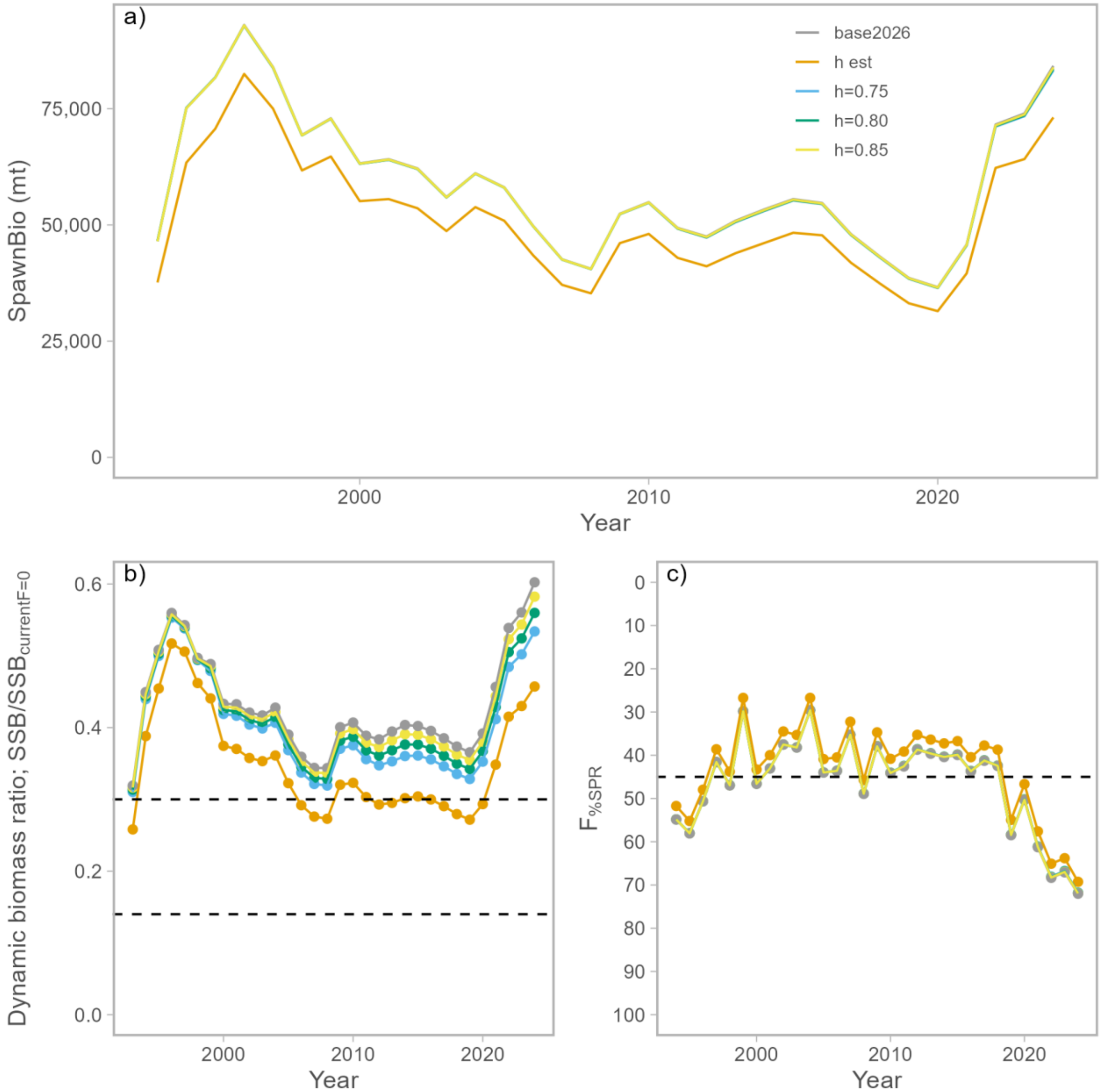


**Figure 11.40**: Estimated female spawning biomass (a), dynamic spawning biomass depletion (b), and fishing intensity ($F_{\%SPR}$; c) for the 2026 base case model (gray), sensitivity run with steepness values fixed at 0.75 (blue), 0.8 (green), and 0.85 (yellow), and estimated with a prior (orange).

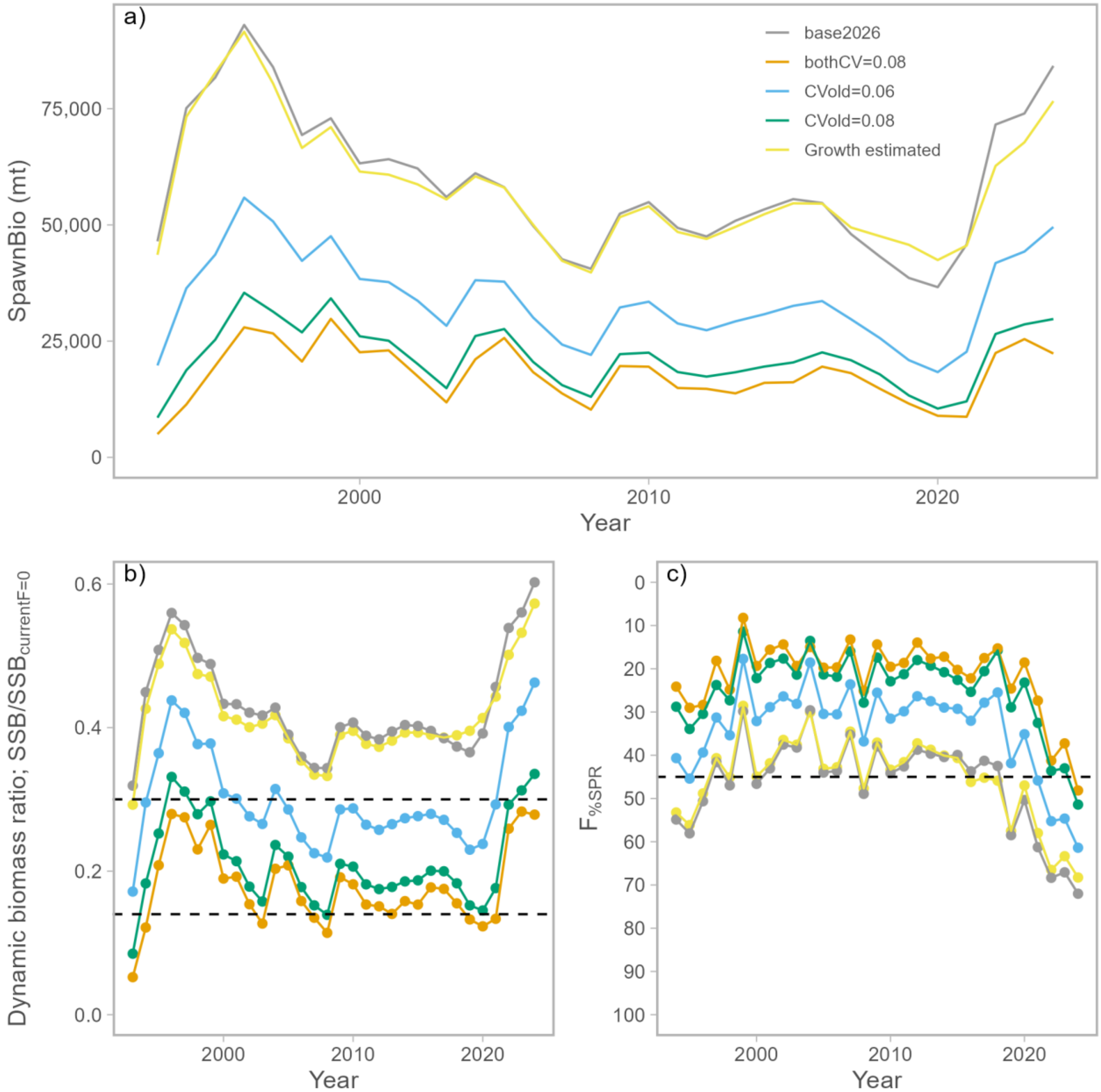


**Figure 11.41**: Estimated female spawning biomass (a), dynamic spawning biomass depletion (b), and fishing intensity ($F_{\%SPR}$; c) for the 2026 base case model (gray), sensitivity runs with CV of $L_{inf}$ and $L_1$ = 0.08 (orange), CV of $L_{inf}$ = 0.06 (blue), CV of $L_{inf}$ = 0.08 (green), and all growth parameters estimated for each sex.


**Figure 11.42**: Estimated female spawning biomass with downweighting of each individual fleet. Panels are arranged by fishery type.

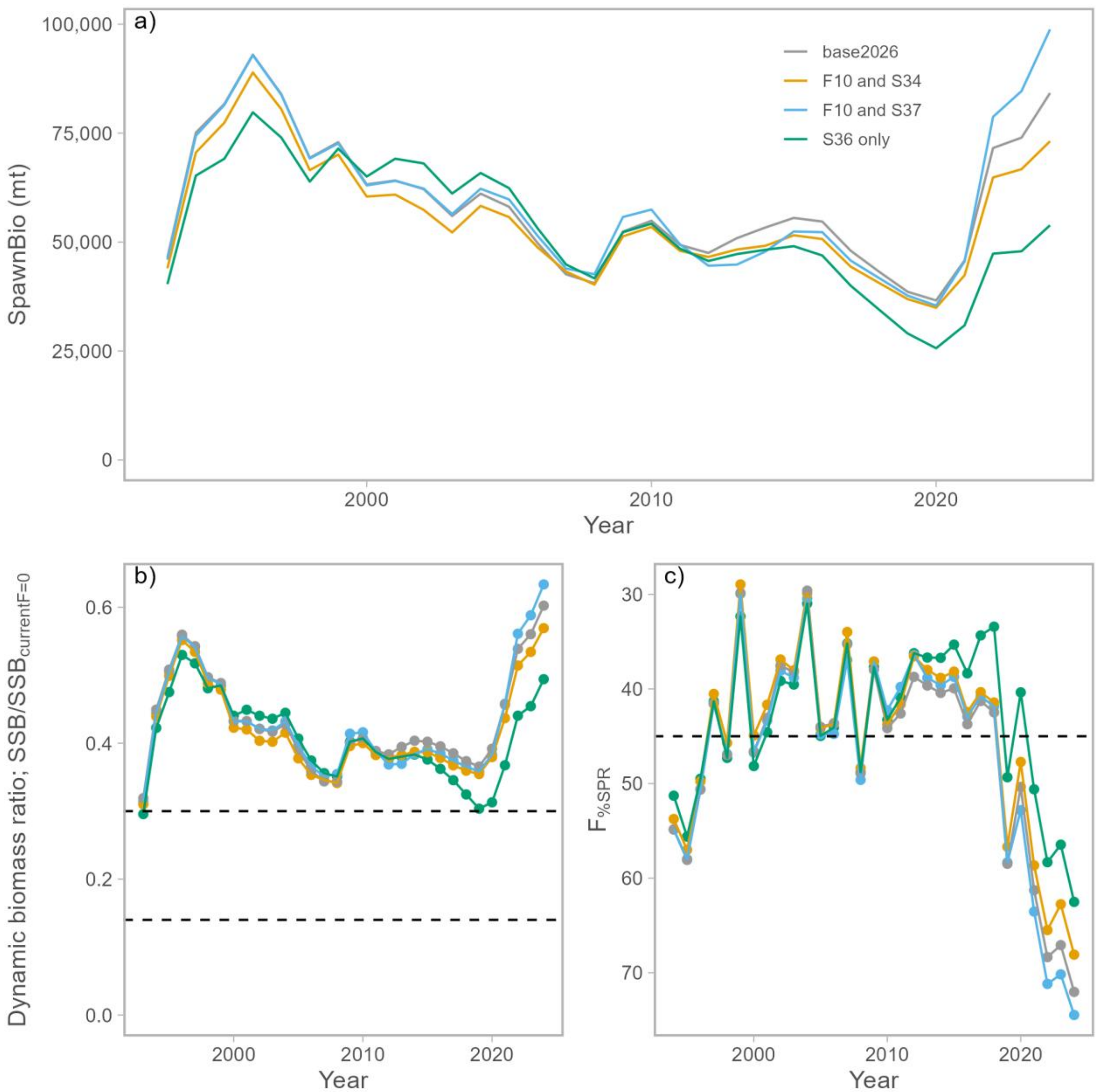


**Figure 11.43**: Estimated female spawning biomass (a), dynamic spawning biomass depletion (b), and fishing intensity ($F_{\%SPR}$; c) for the 2026 base model (gray), F10 and F34 indices (orange), F10 and S37 indices (blue), and S36 index only (green).

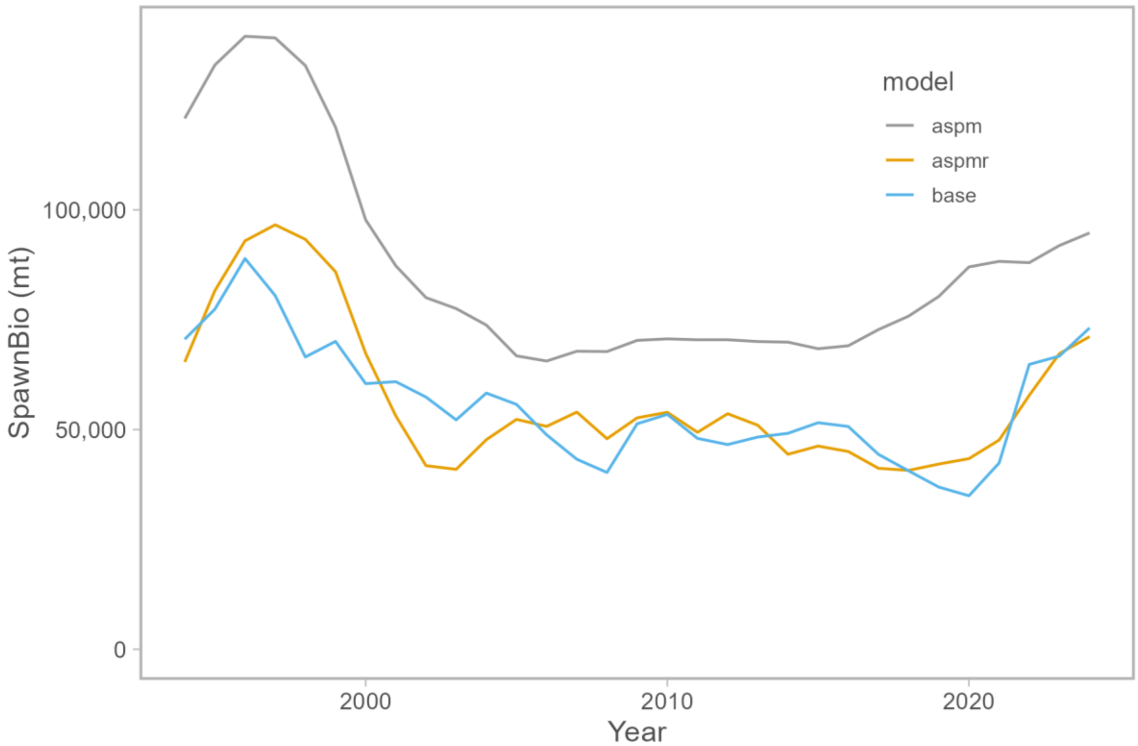


**Figure 11.44**: Estimated female spawning stock biomass from the base case sensitivity fitted to F10 + F34 indices of abundance (blue), ASPM (gray), and ASPM-R (orange) models.

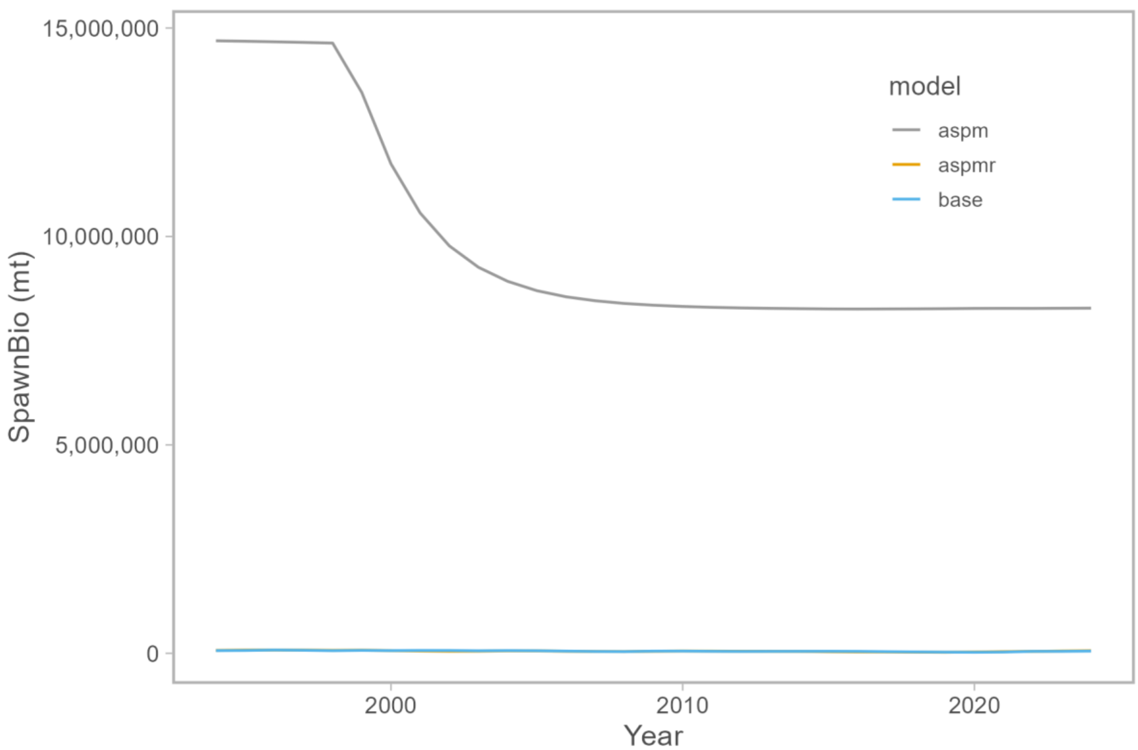


**Figure 11.45**: Estimated female spawning stock biomass from the base case sensitivity fitted to S36 index of abundance (blue), ASPM (gray), and ASPM-R (orange) models.

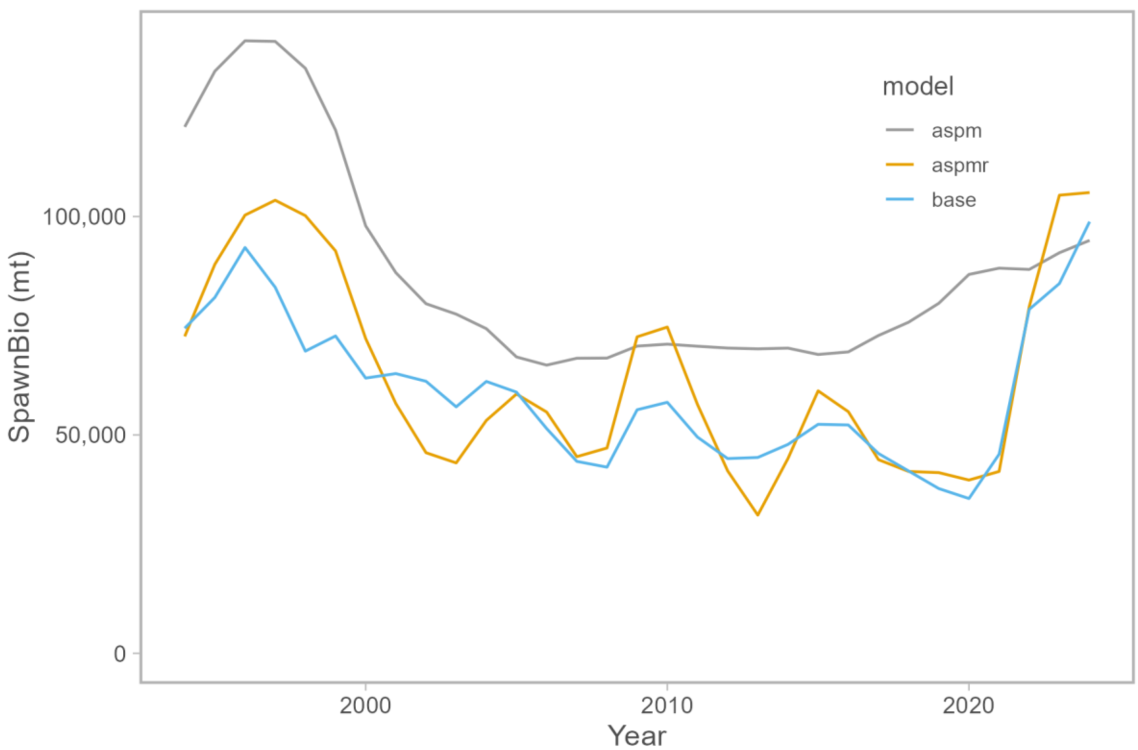


**Figure 11.46**: Estimated female spawning stock biomass from the base case sensitivity fitted to F10 + S37 indices of abundance (blue), ASPM (gray), and ASPM-R (orange) models.

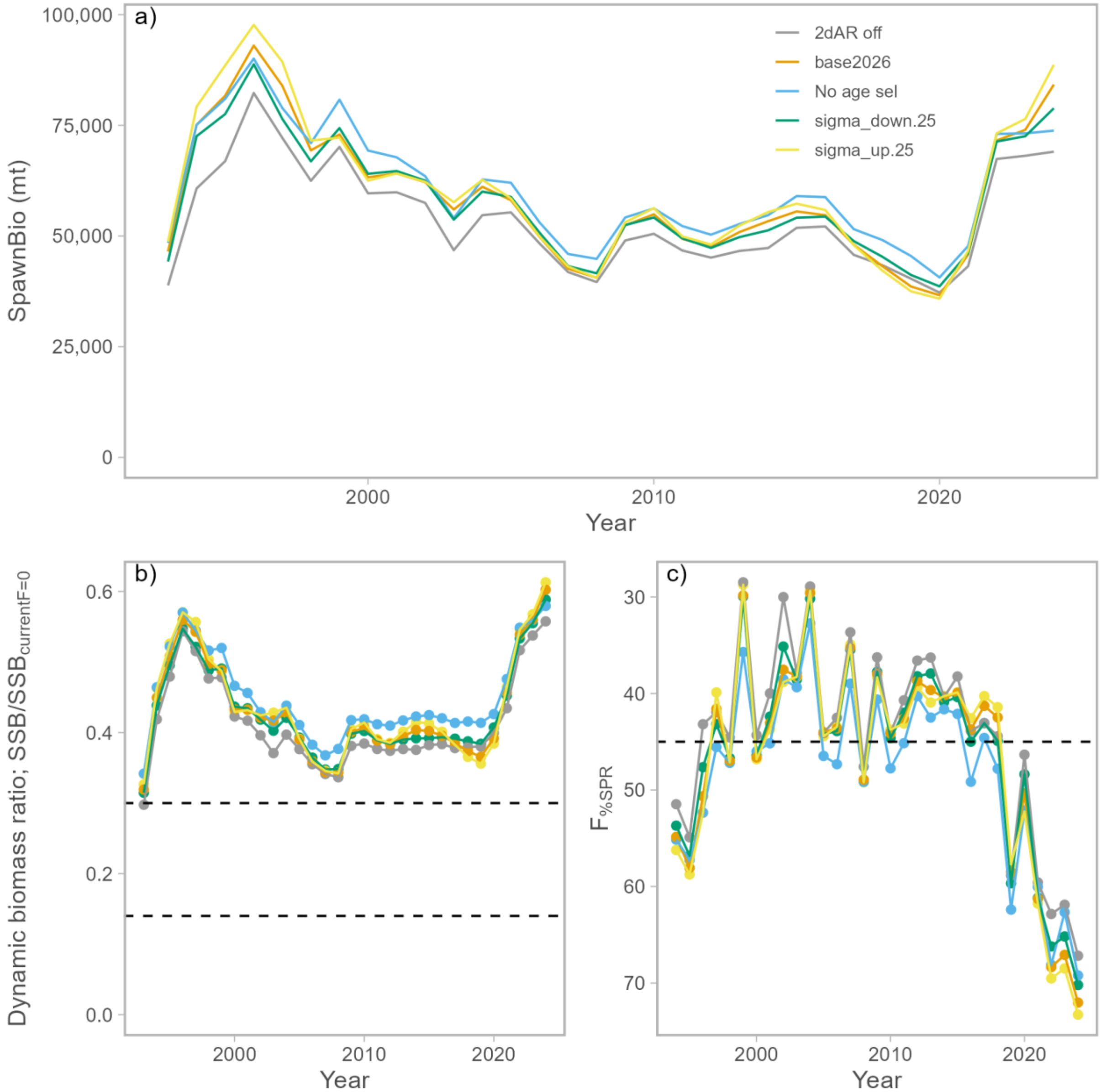


**Figure 11.47**: Estimated female spawning biomass (a), dynamic spawning biomass depletion (b), and fishing intensity ($F_{\%SPR}$; c) from the sensitivities with 2DAR $\sigma$ increased by 0.25 (yellow), decreased by 0.25 (green), 2DAR selectivity turned off (gray), no age selectivities estimated (blue) and the base model (orange).

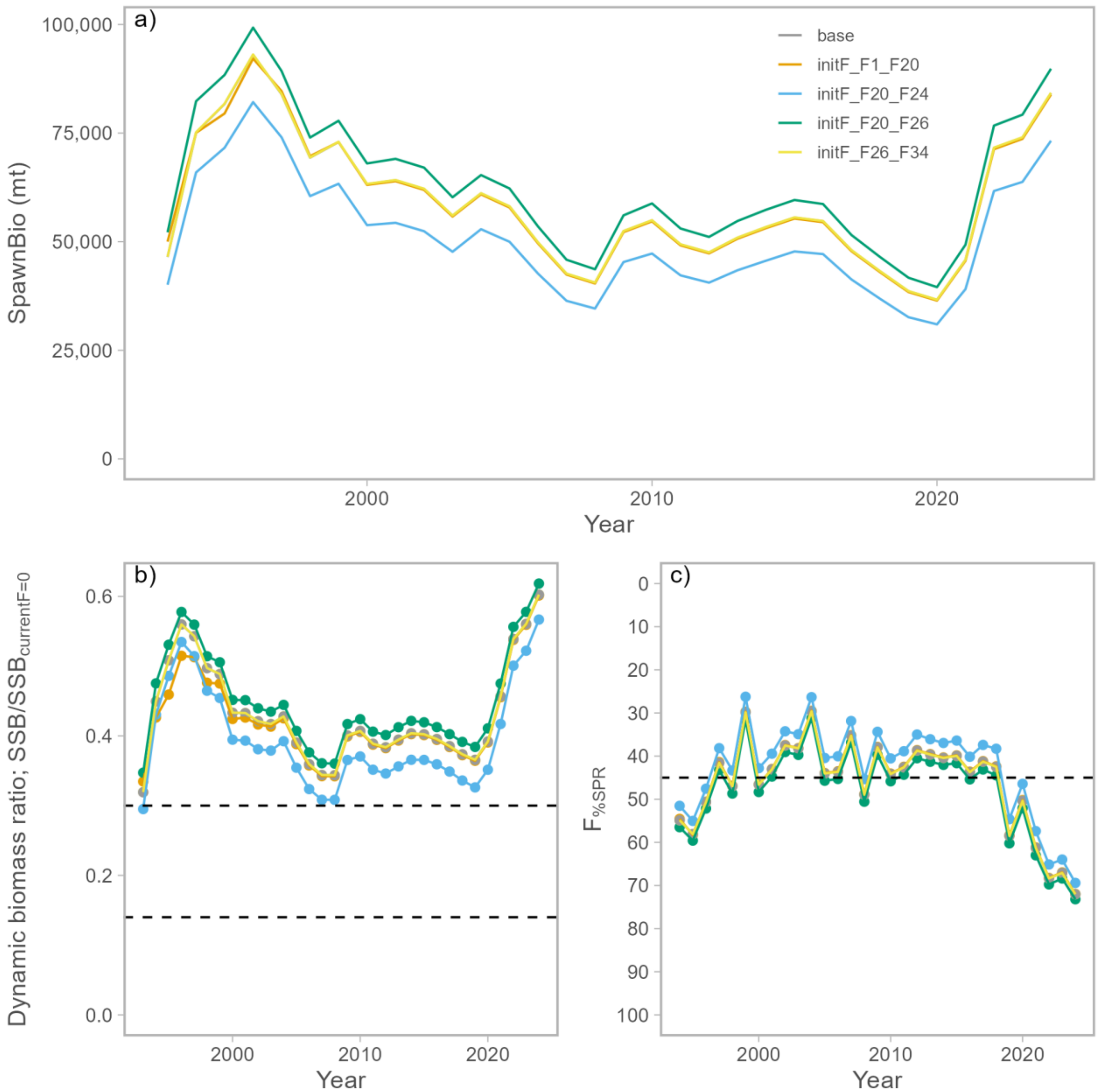


**Figure 11.48**: Estimated female spawning biomass (a), dynamic spawning biomass depletion (b), and fishing intensity ($F_{\%SPR}$; c) from the sensitivities with 2DAR $\sigma$ increased by 0.25 (yellow), decreased by 0.25 (green), 2DAR selectivity turned off (gray), no age selectivities estimated (blue) and the base model (orange).

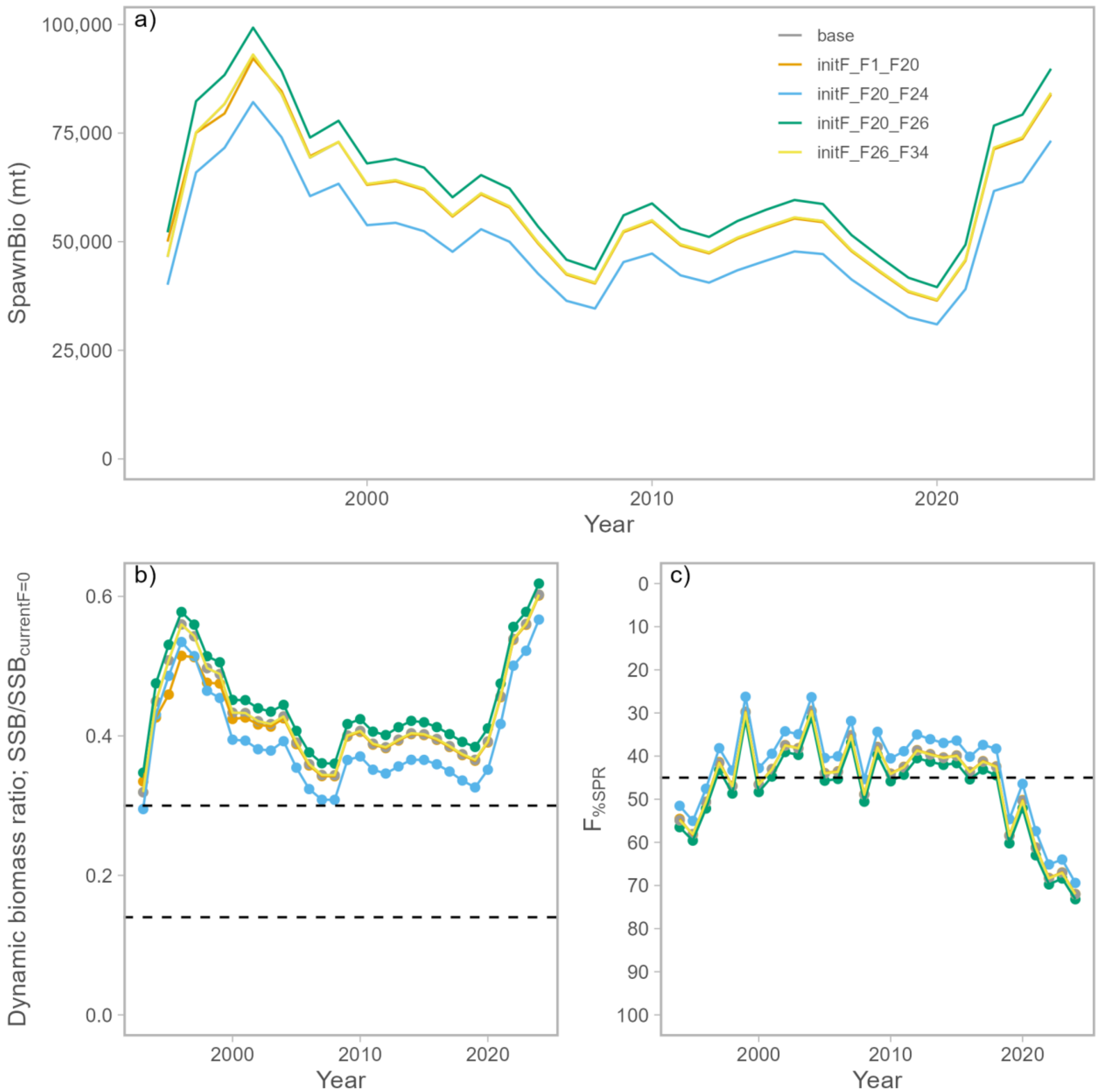


**Figure 11.49**: Estimated female spawning biomass (a), dynamic spawning biomass depletion (b), and fishing intensity ($F_{\%SPR}$; c) from the sensitivities for the 2026 base model (gray) and 2023 model with 2026 data (orange).

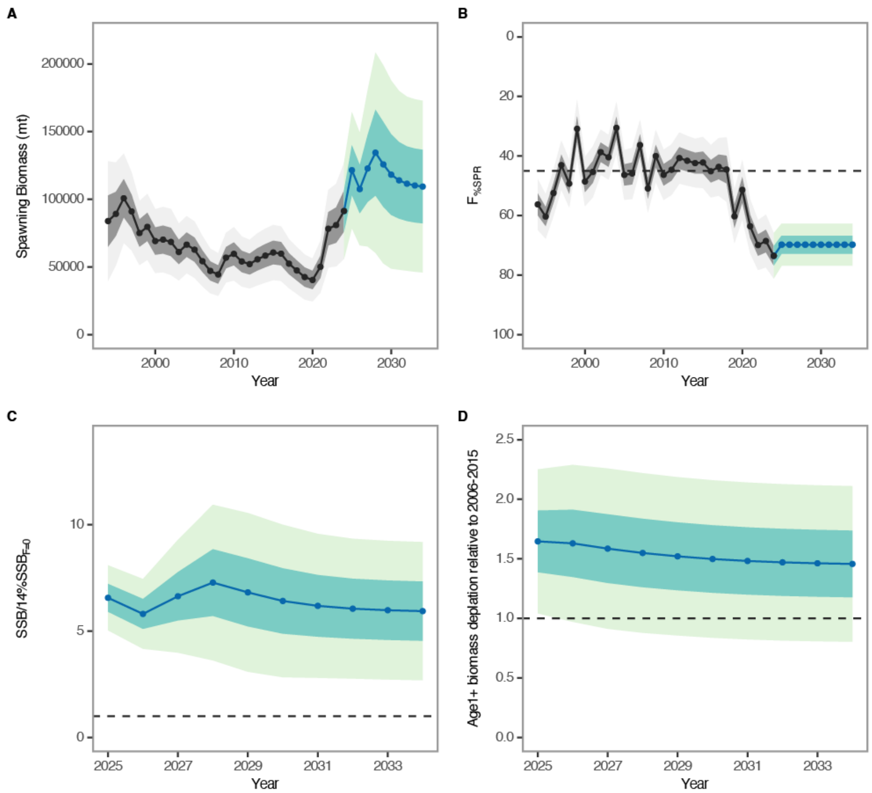


**Figure 11.50**: Future projection results under a constant fishing intensity (F2021-2023) harvest scenario. Solid lines indicate mean values, uncertainty ranges indicate 60% and 95% confidence intervals, and the dashed line is the reference point, respectively. (A) Annual changes in spawning biomass; (B) Interannual changes in fishing mortality (F%SPR); (C) Projected ratios to the limit reference point thresholds; and (D) Projected ratios to management targets for the total biomass.

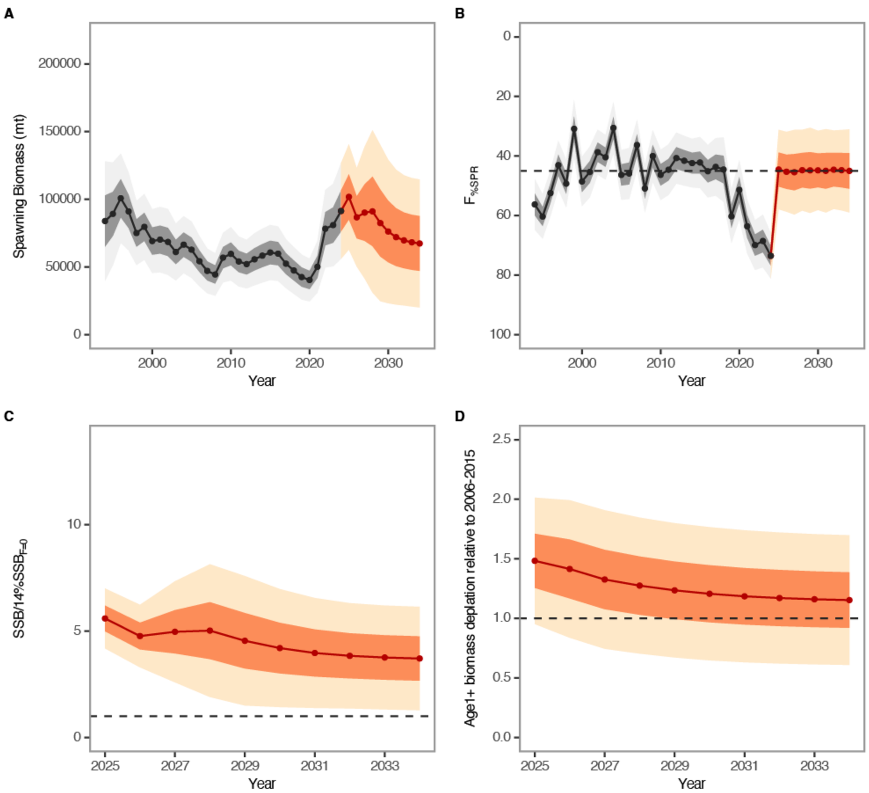


**Figure 11.51**: Future projection results under a randomly F (2005-2019) scenario. Solid lines indicate mean values, and uncertainty ranges indicate 60% and 95% confidence intervals, and the dashed line is the reference point, respectively. (A) Annual changes in spawning biomass; (B) Interannual changes in fishing mortality (F%SPR); (C) Projected ratios to the limit reference point thresholds; and (D) Projected ratios to management targets for the total biomass.

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# 13 APPENDIX A: Western and Central Pacific Fisheries Commission (WCPFC) stock status and management advice reporting

**Stock assessment and trends**

North Pacific albacore (*Thunnus alalunga*) is considered a single, well-mixed stock distributed throughout the North Pacific Ocean north of the equator (Table A-01, Figure A-01). For the 2026 stock assessment, all available fishery data from International Scientific Committee (ISC) members and contributing fleets were incorporated, including data from both Western and Central Pacific Fisheries Commission (WCPFC) and Inter-American Tropical Tuna Commission (IATTC) regions. The stock was modeled under the assumption of instantaneous mixing across the stock area on a quarterly time step using a fleets-as-areas approach, with no explicit spatial structure.

Catch, standardized catch-per-unit-effort (CPUE), and size composition data were compiled from ISC member countries (Canada, China, Chinese Taipei, Japan, Korea, Mexico, and the USA) and cooperating non-member countries. The primary abundance index used in the base model was the Japanese longline CPUE index (F10; 1996–2024), which was considered the most representative indicator of adult female albacore abundance. Length composition data were available for the majority of fleets, representing surface (troll and pole-and-line) and longline fisheries. Sex composition data were also available for a subset of samples but were not included in the base model.

Biological parameters, including sex-specific growth, natural mortality, and maturity, were based on the best available scientific information from previous studies and were fixed in the base case model. The Beverton-Holt stock recruitment relationship was assumed with a steepness parameter ($h$) of 0.9. The assessment was conducted using an integrated statistical, age-, length-, and sex-structured Stock Synthesis (SS3) model fitted to the CPUE and size composition data within a likelihood-based framework.

A series of sensitivity analyses were conducted to evaluate the influence of model assumptions and data inputs on estimates of biomass and fishing intensity. Model configurations explored uncertainty in key biological parameters (e.g., growth, natural mortality, steepness), fishery processes (e.g., selectivity and fleet structure), and input data (e.g., abundance indices, data weighting, and size composition). Additional model runs evaluated alternative assumptions regarding initial conditions, selectivity patterns, and alternative abundance indices (e.g., inclusion of juvenile indices). Key sources of uncertainty considered in the assessment are summarized in Table A-02.

Total reported catch of North Pacific albacore increased from the beginning of the assessment period to a maximum of approximately 119,000 t in 1999 (Figure NPALB-02). Since the early 2000s, catches have declined and stabilized, with recent catches averaging approximately 45,000 t since 2021. Surface gears, which primarily target juvenile albacore, have historically accounted for the majority of the catch (~51%), while longline fisheries, which target older age classes, account for approximately 45% of removals. Japanese fleets have dominated the catch in recent years, followed by USA and Chinese Taipei fleets.

Trends in the primary CPUE index (F10) indicate moderate fluctuations in relative abundance over time, with declines in the early 2000s followed by more stable or increasing trends in recent years (Figure A-03). Because this index reflects adult female abundance during the spawning season, it was considered informative for both population trends and population scale. However, CPUE trends may also reflect changes in availability, spatial distribution, or fishery behavior, and therefore contribute to uncertainty in the assessment.

Estimated recruitment showed substantial interannual variability throughout the assessment period (Figure NPALB-04c), with several strong year classes in recent years (e.g., 2017, 2019, and 2022). These strong recruitment events contributed to increases in total biomass estimates after 2018 (Figure NPALB-04a/b). However, recruitment estimates in the terminal years (2020–2024) are highly uncertain and should be interpreted with caution.

Fishing intensity, expressed as spawning potential ratio (SPR), has declined in recent years (Figure A-05b). The average fishing intensity for 2021–2023 was estimated at F66%SPR, which is below the target reference point (F45%SPR), indicating relatively moderate exploitation levels. Historically, fishing intensity exceeded the target reference point during the late 1990s through the mid-2010s but has remained below the target since approximately 2019.

Estimates of total biomass (age-1+) declined from the beginning of the assessment period through the early 2000s, remained relatively stable until the late 2010s, and increased thereafter due to strong recruitment (Figure A-04). Female spawning stock biomass (SSB) followed a similar trajectory, with an initial decline until approximately 2007, followed by fluctuations without a clear long-term trend through 2020, and increases in the most recent years. The estimated SSB in 2024 represents approximately 60% of the unfished spawning biomass ($SSB_{current,F=0}$) and has remained well above both the threshold and limit reference points throughout the assessment period.

The 2026 assessment builds on previous assessments (2017, 2020, and 2023) and incorporates several updates to model structure and data inputs, including revisions to the primary CPUE index, updates to fleet structure, implementation of time-varying selectivity using a two-dimensional autoregressive approach, and inclusion of additional size composition data from China and Vanuatu fleets. These changes improved model fit and stability but did not fundamentally alter the overall trends in biomass and fishing intensity observed in previous assessments.

Overall, the results of the 2026 stock assessment indicate that the North Pacific albacore stock has experienced moderate exploitation, with recent increases in biomass driven by strong recruitment, and current fishing intensity levels below the target reference point (Table A-03).

***Stock status***

Estimated summary biomass (males and females at age-1+) declined at the beginning of the time series until 2004. Subsequently, the summary biomass fluctuated without a clear trend until 2018, after which the biomass increased to values higher than those at the beginning of the model time period. It should be noted that the high summary biomass estimates since 2018 also had increasing uncertainty. These high summary biomass estimates can be largely attributed to several strong recruitment estimates in 2017 (~297 million fish; 95% CI: 215– 381million fish), 2019 (~292 million fish; 95% CI: 187 to 396 million fish), and 2022 (~314 million fish; 95% CI: 93-536 million fish). However, it should be noted that the recruitment estimates in the last 5 years (2020-2024) were highly uncertain and should be treated with caution. Estimated female SSB exhibited a similar trend to the summary biomass, albeit with a lag of several years, and showed an initial decline until 2007 followed by fluctuations without a clear trend through 2020 (Figure A-04).

The average fishing intensity during 2021 – 2023 was estimated to be $F66_{\%SPR}$ (95% CI: $F74_{\%SPR}$ – $F57_{\%SPR}$), which was relatively moderate and resulted in a population with an SPR of approximately 66%. Instantaneous fishing mortality at age (F-at-age) was similar in both sexes through age-5, peaking at age-4 and declining to a low at age-6, after which males experienced higher F-at-age than females up to age 14 (Figure A-06). Juvenile albacore aged 2 to 4 years comprised approximately 76% of the annual catch-at-age in numbers between 1994 and 2024 (Figure A-07) due to the larger fishery impact of surface fisheries (primarily troll, pole-and-line), which remove juvenile fish, relative to longline fisheries, which primarily remove adult fish (Figure A-08).

Stock status is depicted in relation to the target ($F45_{\%SPR}$), threshold ($30\%SSB_{current,F=0}$), and limit ($14\%SSB_{current,F=0}$) reference points (Figure A-05; Table A-03). The estimated female SSB has never fallen below the threshold and limit reference points since 1994, albeit with large uncertainty in the terminal year (2024) estimates. The historical fishing intensity was estimated to have exceeded the target reference point for most years between 1997-2018. However, the estimated fishing intensity has been declining since 2019 and has been below the target reference point for the last six years. Even when alternative hypotheses about key model uncertainties such as growth were evaluated, the point estimate of female SSB in 2024 (SSB2024) did not fall below the threshold and limit reference points (Figure A-09). Estimated average fishing intensity during 2021-2023 (F2021-2023) did not exceed the target reference point under the alternative hypotheses (Figure A-09; Table A-03). Average fishing intensity from 2021-2023 also did not exceed the average fishing intensity during 2002-2004 (Table A-03).

The SSB2024 was estimated to be approximately 60% (95% CI: 38 – 83%) of $SSB_{current,F=0}$ and 2.01 (95% CI: 1.26 – 2.76) times greater than the estimated threshold reference point (Table A-03). The estimated current fishing intensity (F2021-2023) was estimated to be $F66_{\%SPR}$ (95% CI: $F74_{\%SPR}$ – $F57_{\%SPR}$) and was lower than both the $F45_{\%SPR}$ target reference point and the average fishing intensity during 2002 – 2004 (Table A-03). Based on these findings, the following information on the status of the north Pacific albacore stock is provided:

3. **The stock is virtually certain (>99%) not to be overfished relative to the threshold ($30\%SSB_{current,F=0}$) and limit ($14\%SSB_{current,F=0}$) reference points adopted by the WCPFC and IATTC, and**
4. **The stock is virtually certain (>99%) to be not experiencing overfishing relative to the target reference point ($F45_{\%SPR}$).**

### *Conservation Information*

The constant fishing intensity scenario showed that the current fishing intensity (F2021-2023) is expected to result in female SSB increasing to 109,384 t (95% CI: 82,915 – 136,573 t) and a $SSB/SSB_{current,F=0}$ ratio of 0.83 by 2034. Over the next 10 years, there was: 1) a 100.0% probability of the female SSB remaining above the $14\%SSB_{current,F=0}$ LRP for all 10 years; 2) a 86.5% probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 95.3% probability of the fishing intensity remaining at or below the $F45_{\%SPR}$ TRP for any year (Figure A-10). For the second scenario, the period 2005–2019 was chosen because IATTC and WCPFC implemented the current management measures (WCPFC CMM 2019-03; IATTC Resolution C-05-02) that maintains albacore fishing effort at or below the average effort levels during 2002–2004 but before recent declines in F after 2020. If future fishing intensity is similar to the 2005 – 2019 period, it is expected to result in female SSB increasing to 67,340 t (95% CI: 47,082 – 87,597 t) and a $SSB/SSB_{current,F=0}$ ratio of 0.52 by 2034. Over the next 10 years, there was: 1) a 99.1 % probability of the female SSB remaining above the $14\%SSB_{current,F=0}$ LRP for all 10 years; 2) a 79.9 % probability of the total biomass (age-1+) depletion being above the average of 2006 – 2015 for any year; and 3) a 48.8% probability of the fishing intensity remaining at or below the $F45_{\%SPR}$ TRP for any year (Figure A-11).

Based on these findings, the following conservation information is provided:

1. **If fishing intensity over the next 10 years is maintained at the current fishing intensity (F2021-2023), then female SSB is expected to increase to around 83% of $SSB_{current,F=0}$ (109,384 t) by 2034, with a 100.0% probability that female SSB will remain above the $14\%SSB_{current,F=0}$ LRP for all 10 years and the harvest strategy management objectives of the IATTC and WCPFC (IATTC Resolution C-23-02; WCPFC Harvest Strategy 2023-01) will likely be met; and**

2. **If fishing intensity over the next 10 years is similar to the 2005 – 2019 period, then female SSB is expected to decrease to around 52% of $SSB_{current,F=0}$ (67,340 t), with a 99.1 % probability that female SSB will remain above the $14\%SSB_{current,F=0}$ LRP for all 10 years and the harvest strategy management objectives of the IATTC and WCPFC (IATTC Resolution C-23-02; WCPFC Harvest Strategy 2023-01) will likely be met.**

**Table A-01.** Stock assessment model structure for the 2026 North Pacific Albacore benchmark stock assessment.

| | |
|---|---|
| **Species** | North Pacific albacore (*Thunnus alalunga*) |
| **Stock Area** | North Pacific Ocean (0°N–55°N; single, well-mixed stock) |
| **Assessment Model** | Stock Synthesis (SS3), length-, age-, and sex-structured |
| **Data Period** | 1994–2024 (quarterly time step); CPUE index from 1996–2024 |
| **Primary Fisheries** | Surface fisheries (troll, pole-and-line; major source of juvenile mortality) and longline fisheries (targeting adults) |
| **Key data** | Catch, standardized CPUE (F10 JPLL index), length composition, sex composition (limited) |

**Table A-02**. Key sources of uncertainty considered in the 2026 North Pacific Albacore benchmark stock assessment.

| Source | Type | Rationale | Uncertainty | Impact | Confidence |
|---|---|---|---|---|---|
| **Data** | Catch | Best available information | Some uncertainty in reported catches, including potential unreported removals and historical differences across fleets | Misreporting or missing catch can bias total removals and affect biomass estimates | Medium |
| | Initial Conditions | Estimated from early catch and equilibrium assumptions | Pre-1994 stock conditions uncertain due to missing or unreliable earlier data (e.g., drift net fisheries) | Initial population size and depletion depend on assumptions about early stock status | Medium |
| | CPUE | Best available information (primarily F10 JPLL index) | CPUE may reflect changes in availability, spatial distribution, or fishing practices rather than abundance alone | Misinterpretation of abundance trends and population scale | Medium |
| | Size data | Extensive but variable across fleets | High variability in size composition (especially for juvenile-dominated surface fisheries); some fleets have incomplete or uncertain sampling | Influences selectivity estimates, age structure, and recruitment estimation | Medium |
| **Spatial Assumptions** | Single-stock (well-mixed) model | Simplified representation of spatial dynamics | Does not explicitly model seasonal and ontogenetic movement of juveniles and adults | May bias estimates of selectivity, availability, and fishing impacts across regions | Medium |

| | | | | | |
|---|---|---|---|---|---|
| **Key Parameters** | Growth | Fixed from external studies (sex-specific von Bertalanffy) | Uncertainty in growth parameters, especially variability (CV of length-at-age) | Strong influence on biomass scaling and reference point estimates | High |
| | Maturity | Fixed maturity ogive from literature | Limited updated information on maturity-at-age or length | Affects spawning stock biomass (SSB) estimates | High |
| | Natural Mortality | Estimated from meta-analysis and life-history relationships | Uncertainty in age- and sex-specific natural mortality rates | Affects productivity, recruitment, and stock status metrics | High |
| | Length-weight | Estimated from empirical relationships | May not represent all fleets or temporal variability | Conversion between length and weight may introduce bias in biomass estimates | Medium |
| **Other Sources of Uncertainty** | Recruitment variability | Estimated within model (Beverton-Holt SRR) | Recent recruitment (last ~5 years) highly uncertain and influential | Drives recent biomass increases and projection outcomes | Medium |
| | Climate and environmental effects | Not explicitly included in model | Environmental variability affects distribution, recruitment, and CPUE | Long-term changes in productivity and spatial structure uncertain | Low |

Table A-03. Estimates of maximum sustainable yield (MSY), female spawning stock biomass (SSB), fishing intensity (F), and reference point ratios for north Pacific albacore tuna for: 1) the base case model; 2) one important sensitivity model due to uncertainty in growth parameters; 3) a model representing an update of the 2023 base case model to 2026 data; and 4) a model representing uncertainty in the specification of initial fishing mortality.$SSB_0$, $SSB_{current,F=0}$, and $SSB_{MSY}$ are the expected female SSB of a population in the equilibrium, unfished state; in the current, dynamic, unfished state; and at MSY, respectively. The Fs in this table are indicators of fishing intensity based on spawning potential ratio (SPR) and calculated as %SPR. SPR is the ratio of the equilibrium SSB per recruit that would result from the estimated F-at-age relative to that of an unfished population. Depletion is calculated as the proportion of the age-1+ biomass during the specified period relative to an unfished age-1+ equilibrium biomass. The model representing an update of the 2023 base case model is similar to but not identical to the 2026 base case model due to changes in data preparation and model structure. †A value of >1 for the depletion ratio indicates higher age-1+ biomass in 2024 relative to the 2006–2015 period. §Higher %SPR values indicate lower fishing intensity levels. ¶Values of >1 for ratios of $F_{\%SPR}$ to $F_{\%SPR}$-based reference points indicate fishing intensity levels lower than the reference points. Table 10.14 in stock assessment report.

| Quantity | Base Case | Growth CVold=0.06 | Update of 2023 base case model to 2026 data* | Initial Conditions initF F20 F24 |
|---|---|---|---|---|
| MSY (t) | 106,578 | 86,675 | 113,793 | 100,322 |
| $SSB_{MSY}$ (t) | 19,360 | 15,878 | 20,524 | 18,316 |
| $SSB_0$ (t) | 139,466 | 113,685 | 147,874 | 131,221 |
| $SSB_{2024}$ (t) | 84,209 | 49,547 | 96,362 | 73,236 |
| $SSB_{current, F=0}$ (2024 estimate) | 139,777 | 107,072 | 151,193 | 129,224 |
| $SSB_{2024}/SSB_{current, F=0}$ | 0.60 | 0.46 | 0.64 | 0.57 |
| $SSB_{2024}/30\%SSB_{current, F=0}$ | 2.01 | 1.54 | 2.12 | 1.89 |
| $SSB_{2024}/14\%SSB_{current, F=0}$ | 4.30 | 3.31 | 4.55 | 4.05 |
| † $Depletion_{2024}/Depletion_{2006\text{-}2015}$ | 1.45 | 1.40 | 1.61 | 1.45 |
| § $F_{\%SPR, 2021\text{-}2023}$ (%SPR) | 65.6 | 51.9 | 68.0 | 62.2 |
| § $F_{\%SPR, 2013\text{-}2023}$ (%SPR) | 50.3 | 36.7 | 53.6 | 46.6 |
| ¶ $F_{\%SPR, 2021\text{-}2023}/F_{\%SPR, MSY}$ | 4.03 | 3.17 | 4.18 | 3.80 |
| ¶ $F_{\%SPR, 2013\text{-}2023}/F45_{\%SPR}$ | 1.12 | 0.82 | 1.19 | 1.04 |
| ¶ $F_{\%SPR, 2021\text{-}2023}/F45_{\%SPR}$ | 1.46 | 1.15 | 1.51 | 1.38 |
| ¶ $F_{\%SPR, 2021\text{-}2023}/F_{\%SPR, 2002\text{-}2004}$ | 1.87 | 2.13 | 1.78 | 1.95 |

Table NPALB-04. Summary of reference points for the 2026 north Pacific albacore tuna (*Thunnus alalunga*) stock assessment.

| | | | |
|---|---|---|---|
| **Terminal Year: 2024** | **Biomass** | Virtually Certain (>99%) to be above target | Stock is not overfished |
| | **Fishing Mortality** | Virtually Certain (>99%) to be above target | Overfishing is not occurring |
| | **Projections** | SSB virtually certain (>99%) to remain above limit reference point | Stock unlikely (<40%) to be overfished at current catch levels |
| | **Recommendation** | No action required to maintain stock above limit reference point | |
| **Reference Points/Management Procedure** | **Reference point** | **Estimate [5%-95%]** | **Comment** |
| Biomass | $30\%SSB_{current,F=0}$ | 41,933 mt [33,967-49,899] | Threshold reference point |
| | $14\%SSB_{current,F=0}$ | 19,569 mt [15,851-23,286] | Limit reference point |
| Catch | MSY | 106,578 mt [86,192-127,027] | |
| Fishing Mortality (Fishing Intensity) | F45%SPR | 45%SPR | Defined SPR-based reference point; Fishing intensity |
| **Recent Estimates** | | | **Recent Trend/projection** |
| Biomass | $SSB_{2024}$ | 84,209 mt [49,547 – 96,362] | $SSB_{recent}$ increasing |
| Depletion | $SSB_{2024}/SSB_{current,F=0}$ | 0.60 [0.38 – 0.83] | Moderate depletion |
| | $SSB_{2024}/30\%SSB_{current,F=0}$ | 2.01 [1.26 – 2.76] | Well above threshold |
| | $SSB_{2024}/14\%SSB_{current,F=0}$ | 4.30 [3.31 – 4.55] | Well above limit |
| Fishing Mortality (Fishing Intensity) | $F_{2021-2023}$ | F66%SPR [F74–F57%SPR] | $F_{recent}$ Decreasing |
| | $F_{2024}$ | F72%SPR [66%SPR – 78%SPR] | $F_{recent}$ Decreasing |
| Catch | $C_{2021-2024}$ | 45,091 mt | Catch decreasing |
| | $C_{2024}$ | 42,403 mt | Catch decreasing |
| **Status** | | | **Likelihood** |
| Biomass | $SSB_{2024}/30\%SSB_{current,F=0}$ | 2.01 [1.26 – 2.76] | Virtually certain (>99% probability) to be above threshold |
| | $SSB_{2024}/14\%SSB_{current,F=0}$ | 4.30 [3.31 – 4.55] | Virtually certain (>99% probability) to be above limit |

| | | | |
|---|---|---|---|
| Fishing Mortality (Fishing Intensity) | $F_{2021\text{-}2023}$/F45%SPR | 1.46 [1.62-1.30] | Virtually certain (>99% probability) to be below target |
| **Projections** | | | |
| **Constant F ($F_{2021\text{-}2023}$)** | | | |
| Biomass | $SSB_{2034}$ | 109,384 mt [82,915 - 136,573] | Likely (>60% probability) to be above target |
| | $SSB_{2034}$/ $SSB_{current,F=0}$ | 1.37 [0.78 - 1.95] | 100.0% probability of the female SSB remaining above the 14%$SSB_{current,F=0}$ LRP for all 10 years |
| Catch | $C_{2034}$ | 50,710 mt [35,338 t - 76,111] | |
| **Random F (sampled from F in 2005–2019)** | | | |
| Biomass | $SSB_{2034}$ | 67,340 mt [47,082 – 87,597] | Very likely (>90% probability) to be above target |
| | $SSB_{2034}$/ $SSB_{current,F=0}$ | 1.15 [0.60-1.70] | 99.1 % probability of the female SSB remaining above the 14%$SSB_{current,F=0}$ LRP for all 10 years |
| Catch | $C_{2034}$ | 78,016 t [46,974 - 126,542] | |

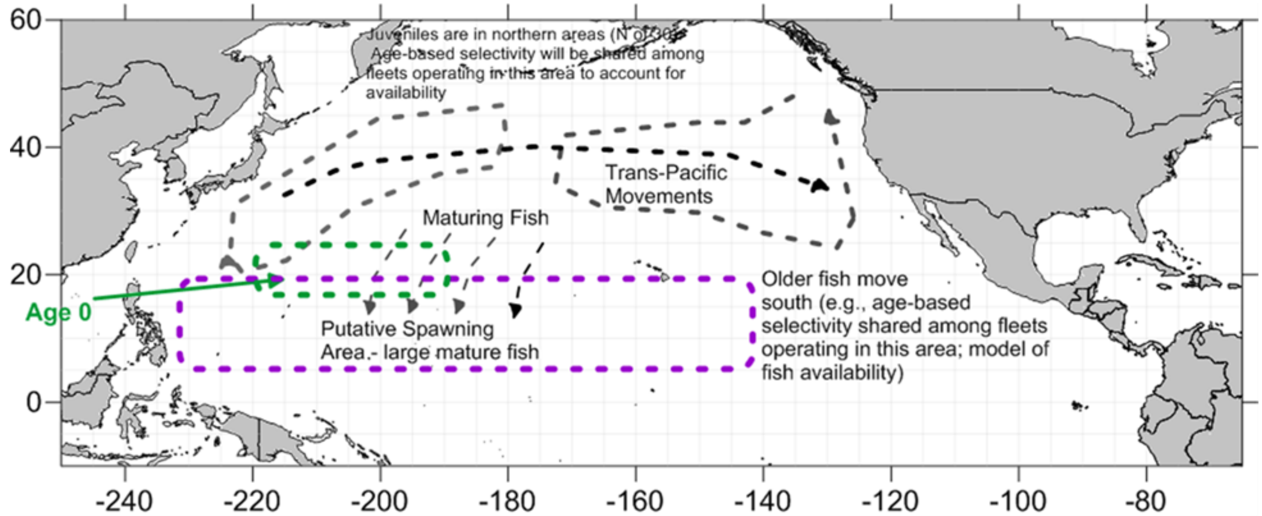


**Figure A-01.** Conceptual model of north Pacific albacore biology and population dynamics. Figure 11.3 in stock assessment report.

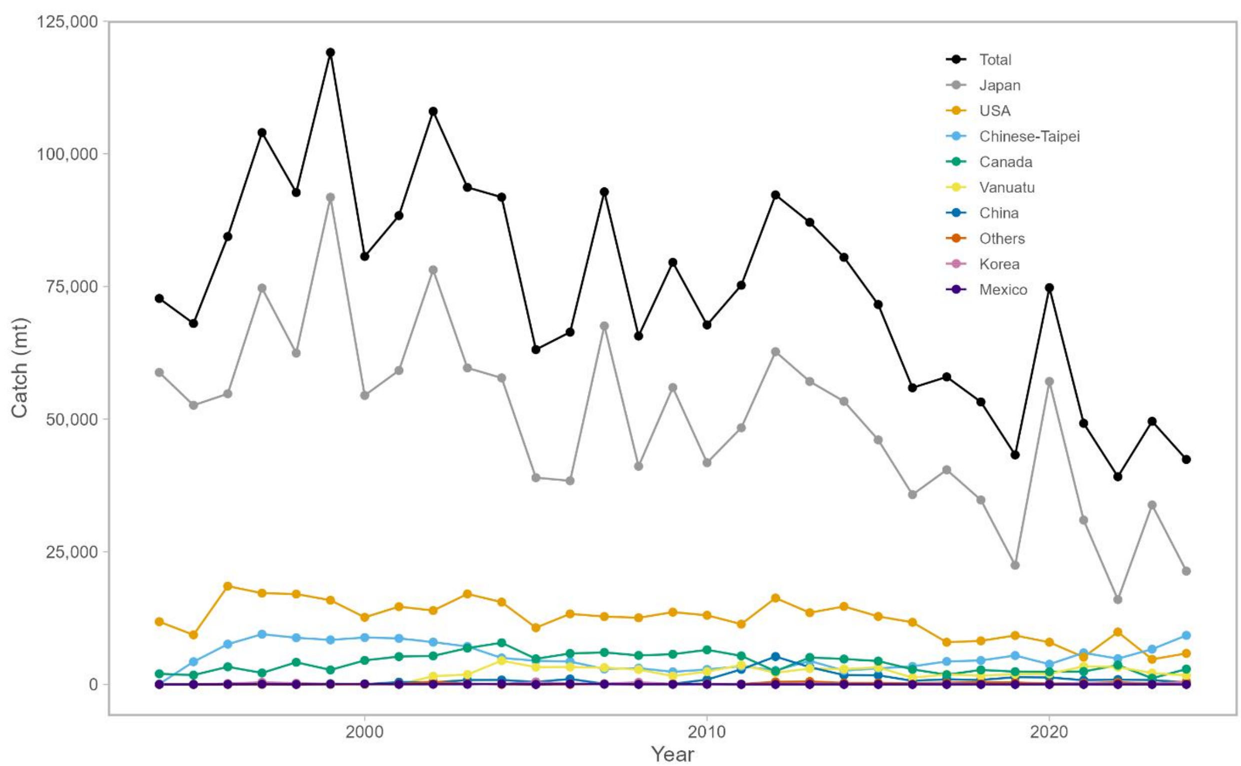


Figure A-02: Estimated total annual catch of north Pacific albacore (*Thunnus alalunga*) by all countries harvesting the stock, 1994-2024. Catches in the “Others” categories includes small amount of catch by other countries such as Kiribati, Belize, Panama, and Marshall Islands. Figure 11.1 in stock assessment report.

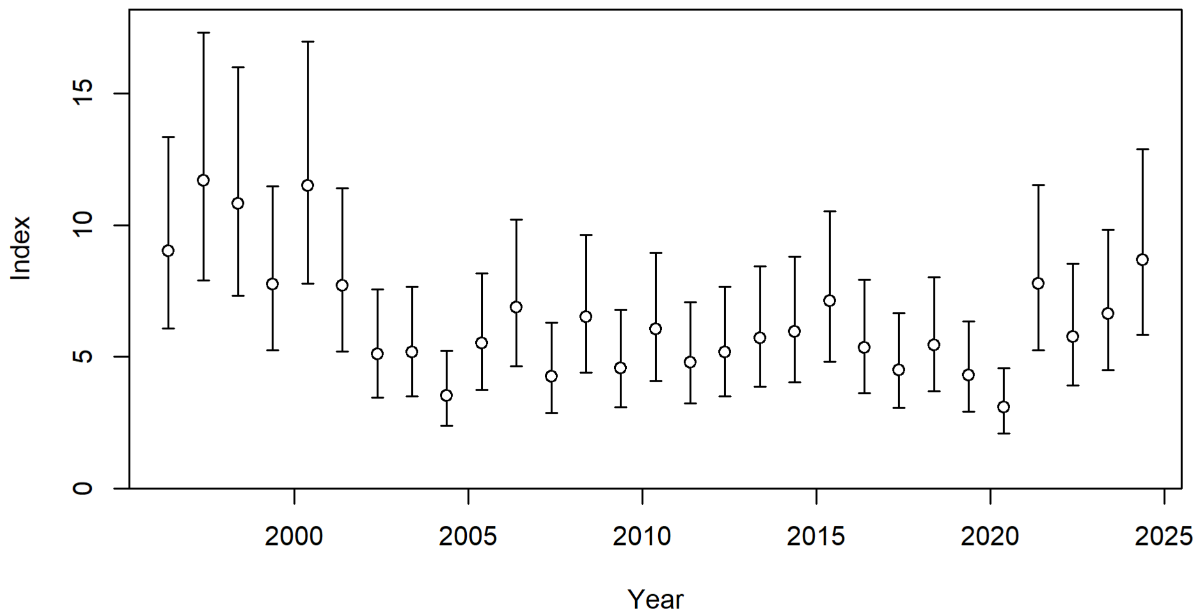


**Figure A-03**: Trends and 95% confidence intervals of the adult index (F10) used in the base case model. Note that the 95% confidence intervals are based on the model assumption of lognormal error, and include both input and additional coefficients of variation (CVs). Figure 11.38 in stock assessment report. Figure 11.8 in stock assessment report.

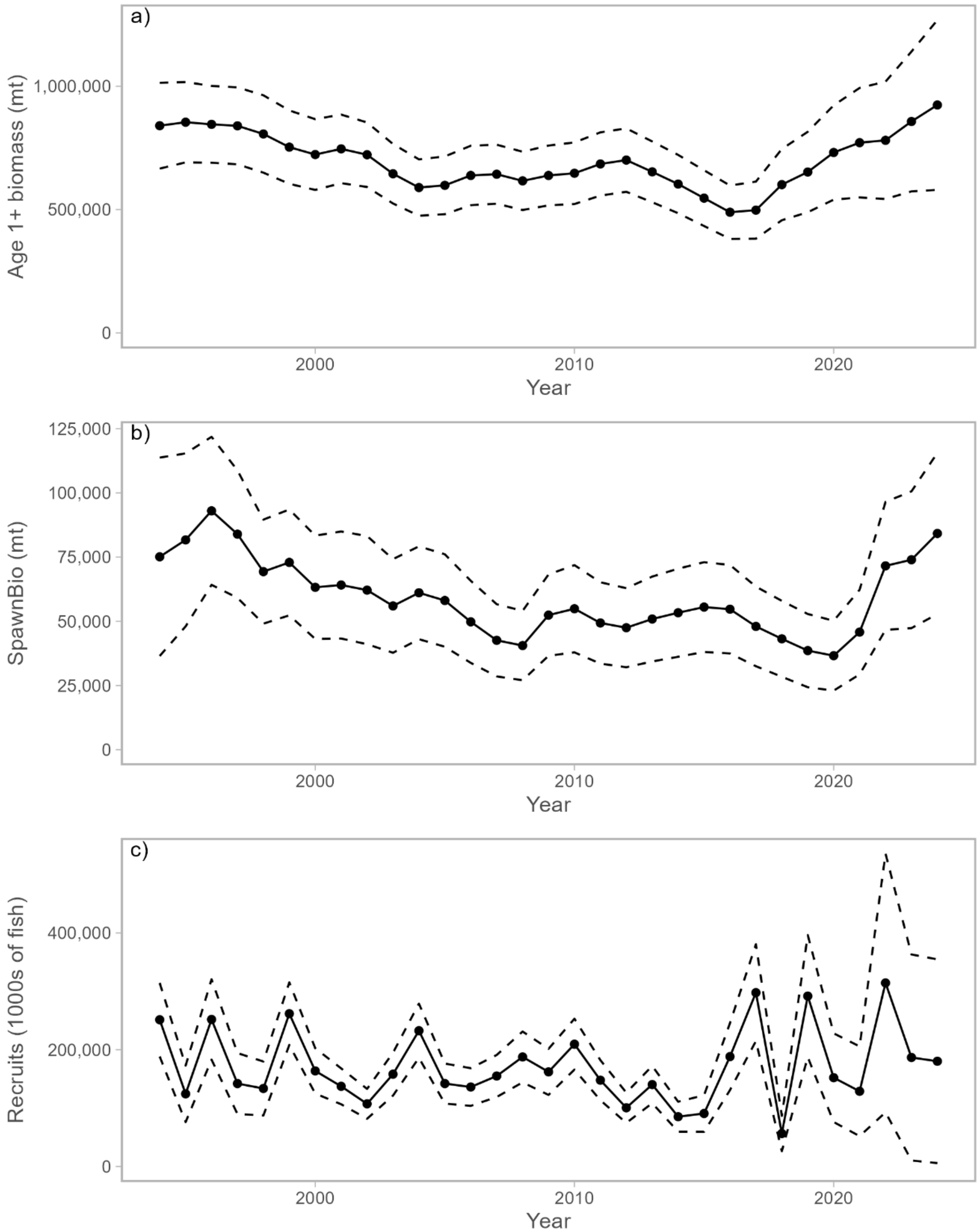


**Figure A-04**: Maximum likelihood estimates of (a) age-1+ biomass, (b) female spawning biomass (SSB), and (c) age-0 recruitment of north Pacific albacore tuna (*Thunnus alalunga*). Dashed lines indicate 95% confidence intervals. Figure 11.34 in stock assessment report.

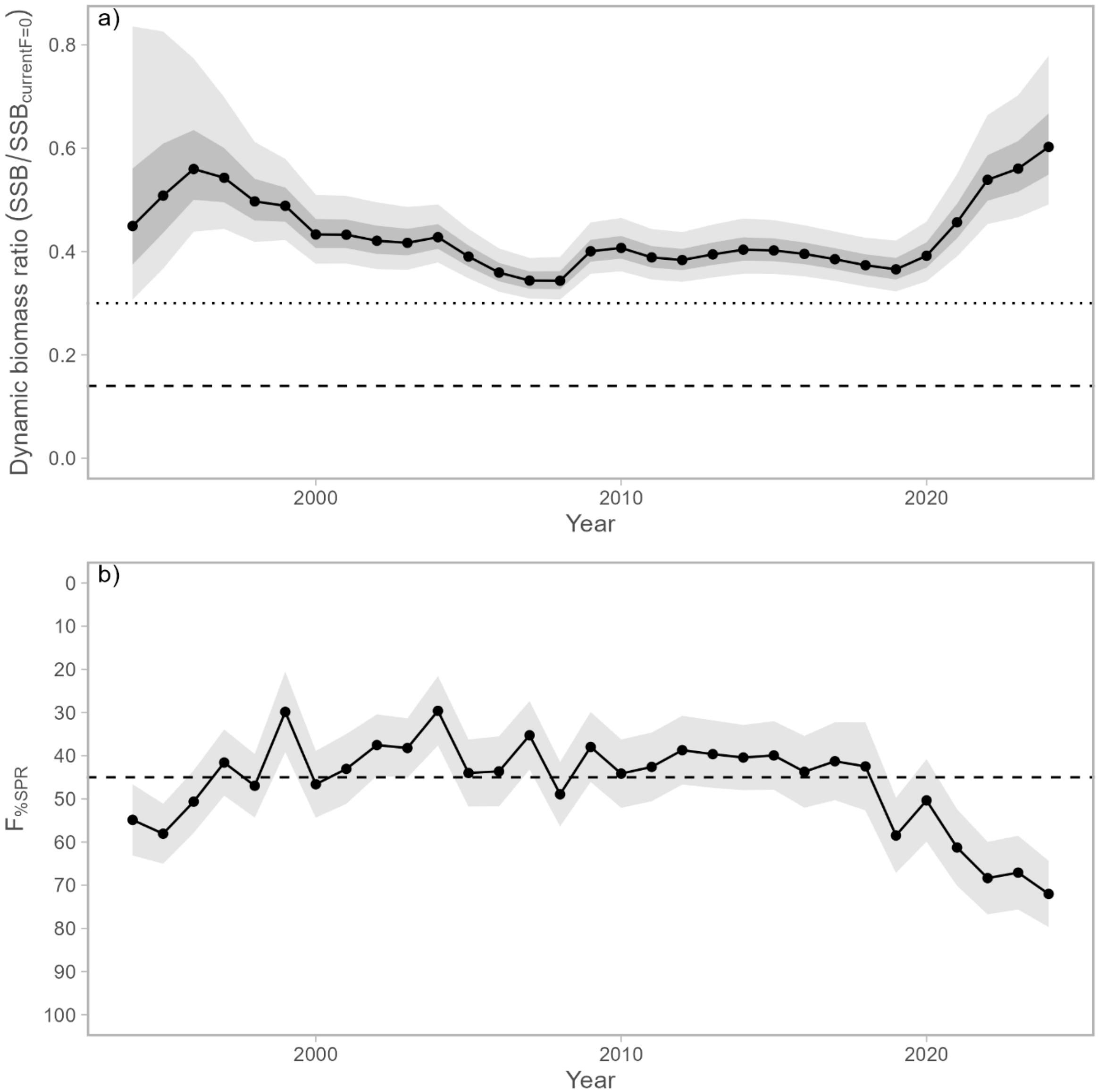


Figure A-05: (A) Estimated dynamic biomass ratio ($SSB/SSB_{current,\ F=0}$) of north Pacific albacore relative to biomass-based threshold ($30\%SSB_{current,\ F=0}$; dotted line) and limit ($14\%SSB_{current,\ F=0}$; dashed line) reference points over the modeling period (1994 – 2024). 95% confidence intervals are indicated by the lighter gray bands and 60% confidence intervals are indicated by the darker gray bands. (B) Estimated fishing intensity relative to the fishing intensity-based target reference point (F45%SPR) over the modeling period (1994 – 2024). The gray area indicates the 95% confidence intervals. The limit reference point is considered to be breached if the lower bound of the 60% confidence intervals overlaps the limit reference point. Figure 11.38 in stock assessment report.

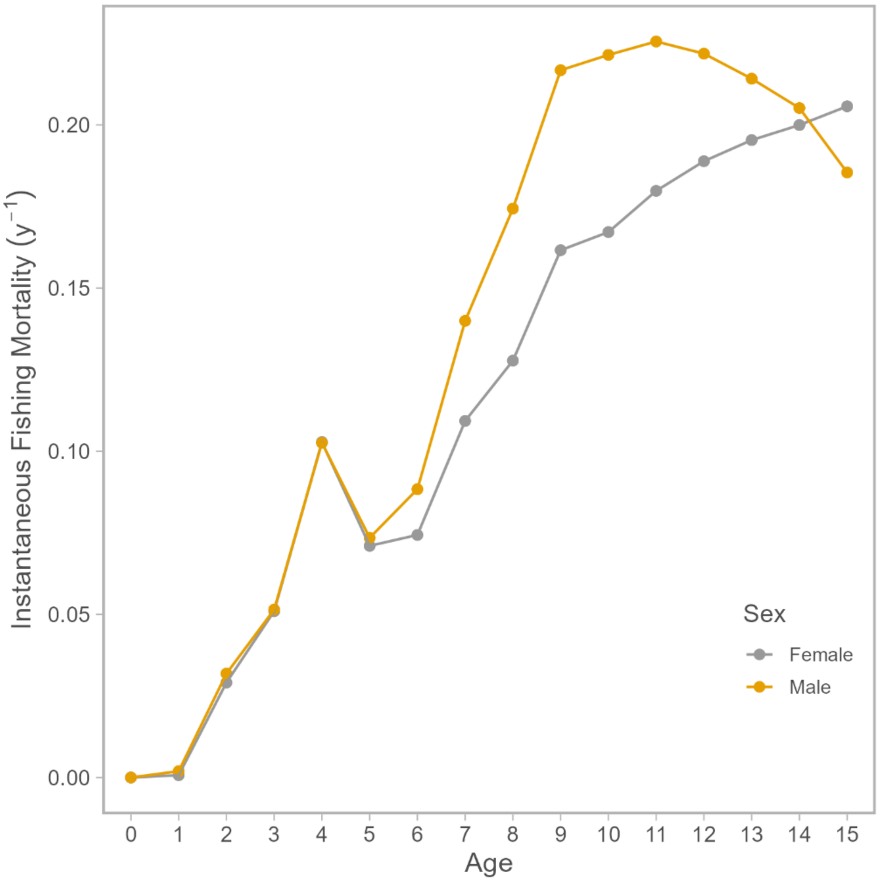


Figure A-06. Estimated sex-specific instantaneous fishing mortality at age (F-at-age) for the 2026 base case model, averaged across 2021-2023. Figure 11.35 in stock assessment report.

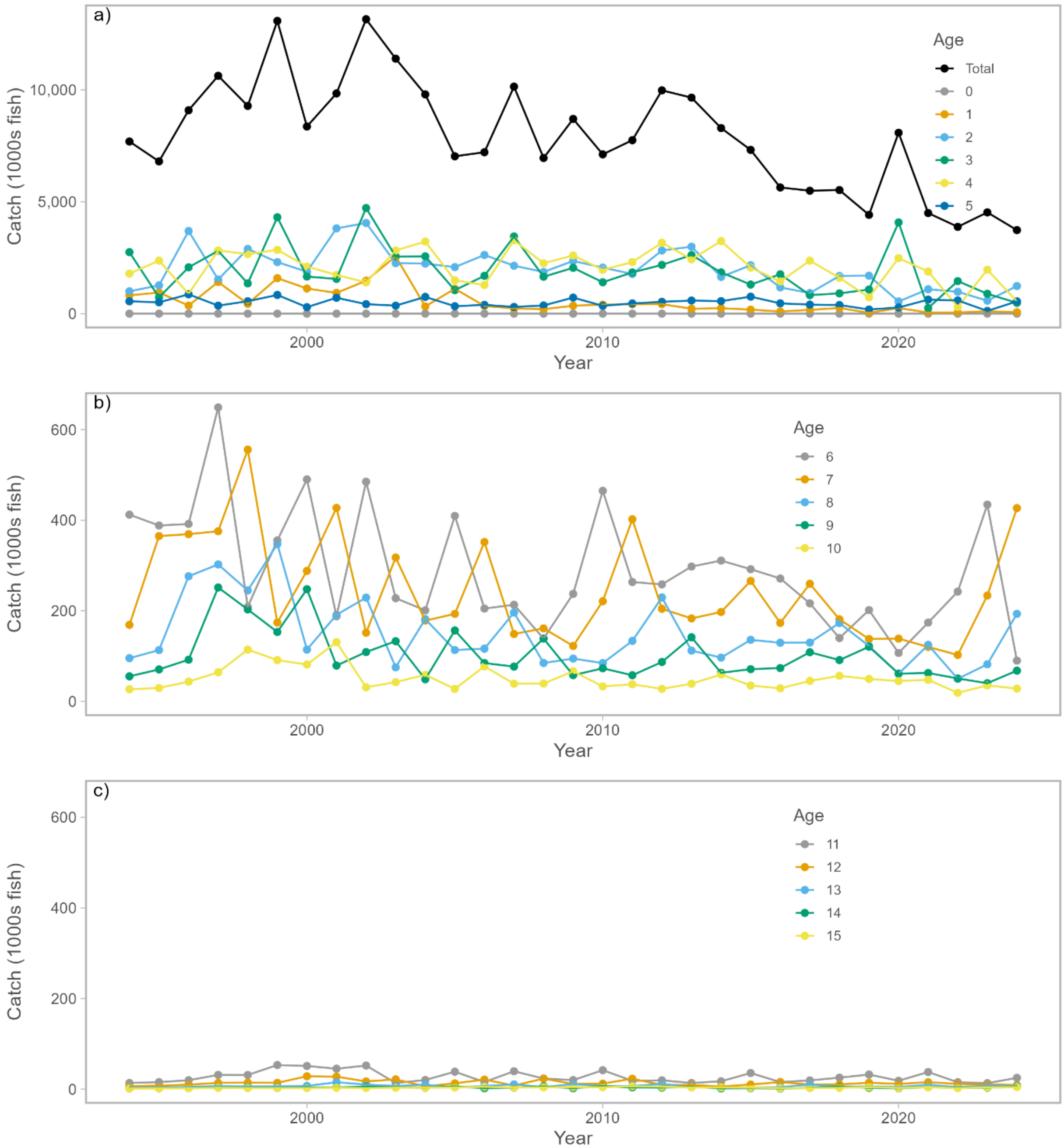


Figure A-07. Historical catch at age of north Pacific albacore estimated by the 2026 base case model. Panels are arranged for the total catch and ages 0-5 (top), 6-10 (middle), and 11-15 (bottom). Note the difference in y-axis scale between the top panel and middle and bottom panels. Figure 11.31 in stock assessment report.

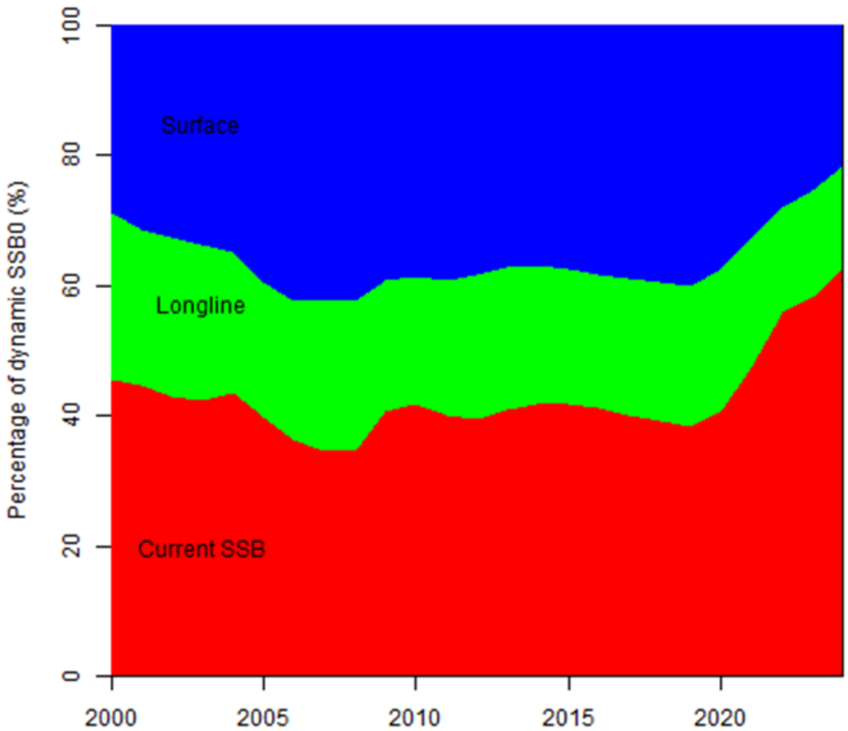


Figure A-08. Fishery impact analysis on north Pacific albacore showing female spawning biomass (SSB; red) estimated by the 2026 base case model as a percentage of dynamic, unfished female SSB (SSB_(current,F=0)). Colored areas show the relative proportion of fishing impact attributed to longline (green) and surface (blue) fisheries (primarily troll and pole-and-line gear, but including all other gears except longline). Figure 11.36 in stock assessment report.

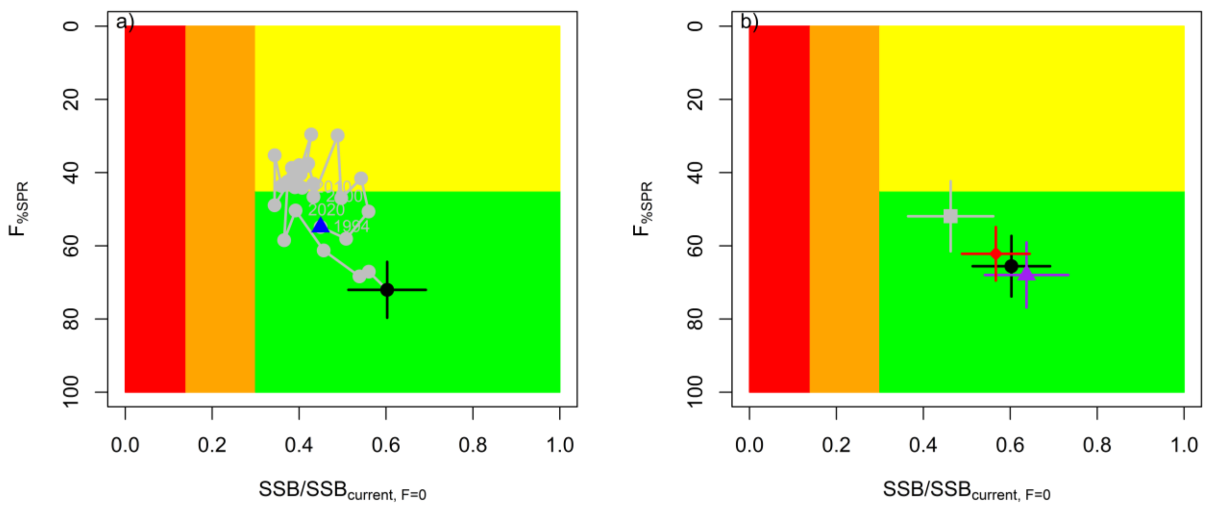


Figure A-09. (a) Stock status phase plot showing the status of the north Pacific albacore (*Thunnus alalunga*) stock relative to the biomass-based threshold (30%$SSB_{current,F=0}$) and limit (14%$SSB_{current,F=0}$) reference points, and fishing intensity-based target reference point (F45%SPR) over the modeling period (1994 – 2024). Blue triangle indicates the start year (1994) and black circle with 95% confidence intervals indicates the terminal year (2024). (B) Stock status plot showing current stock status and 95% confidence intervals of the base case model (black circle), a sensitivity run an important sensitivity run of CV = 0.06 for Linf in the growth model (gray), an important sensitivity run with two initial fishing mortality parameters (red), and a model representing an update of the 2023 base case model to 2026 data (purple). Red zones in both panels indicate female SSBs falling below the limit reference point while the orange zones indicate female SSBs between the threshold and limit reference points. Green zones indicate female SSBs above the threshold reference point and fishing intensity levels below the target reference point. Yellow areas indicate female SSBs above the threshold reference point and fishing intensity levels above the target reference point. The Fs in this figure are indicators of fishing intensity based on spawning potential ratio (SPR) and calculated as %SPR. SPR is the ratio of the equilibrium SSB per recruit that would result from the estimated F-at-age relative to that of an unfished population. A higher %SPR indicates lower fishing intensity. Current fishing intensity values and SSB/SSBcurrent,F=0 ratios in (B) were calculated as the average during 2021-2023 (F%SPR, 2021-2023) and 2024 (SSB2024/SSBcurrent, F=0), respectively. The model representing an update of the 2023 base case model is similar to but not identical to the 2023 base case model due to changes in data preparation and model structure. Figure 11.37 in stock assessment report

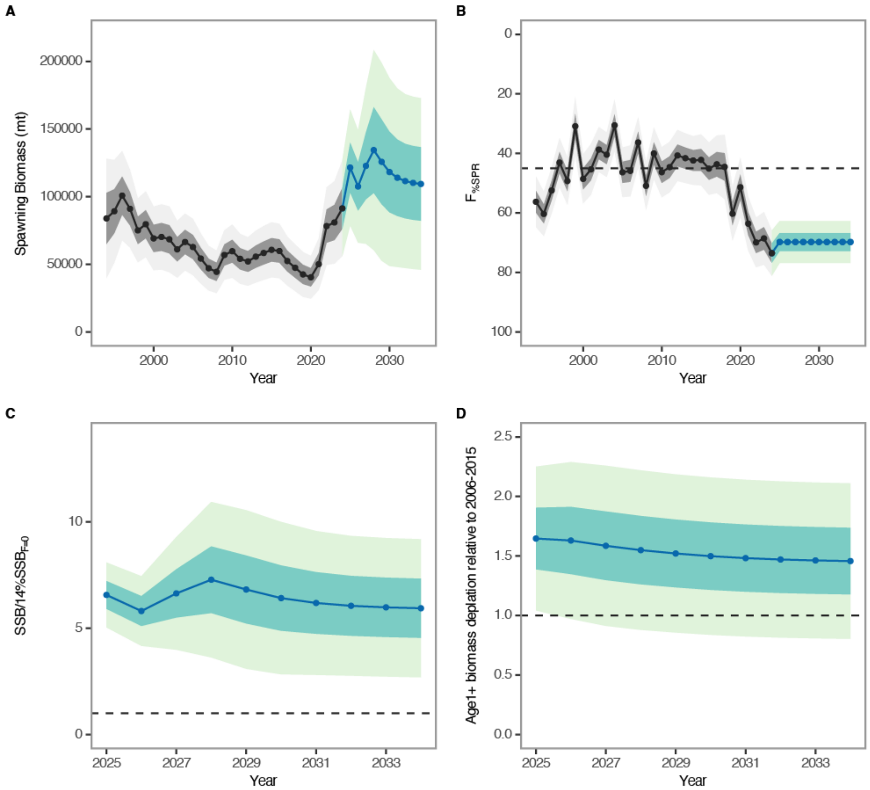


Figure A-10. Future projection results under a constant fishing intensity (F2021-2023) harvest scenario. Solid lines indicate mean values, uncertainty ranges indicate 60% and 95% confidence intervals, and the dashed line is the reference point, respectively. (A) Annual changes in spawning biomass; (B) Interannual changes in fishing mortality (F%SPR); (C) Projected ratios to the limit reference point thresholds; and (D) Projected ratios to management targets for the total biomass. Figure 11.50 in stock assessment report.

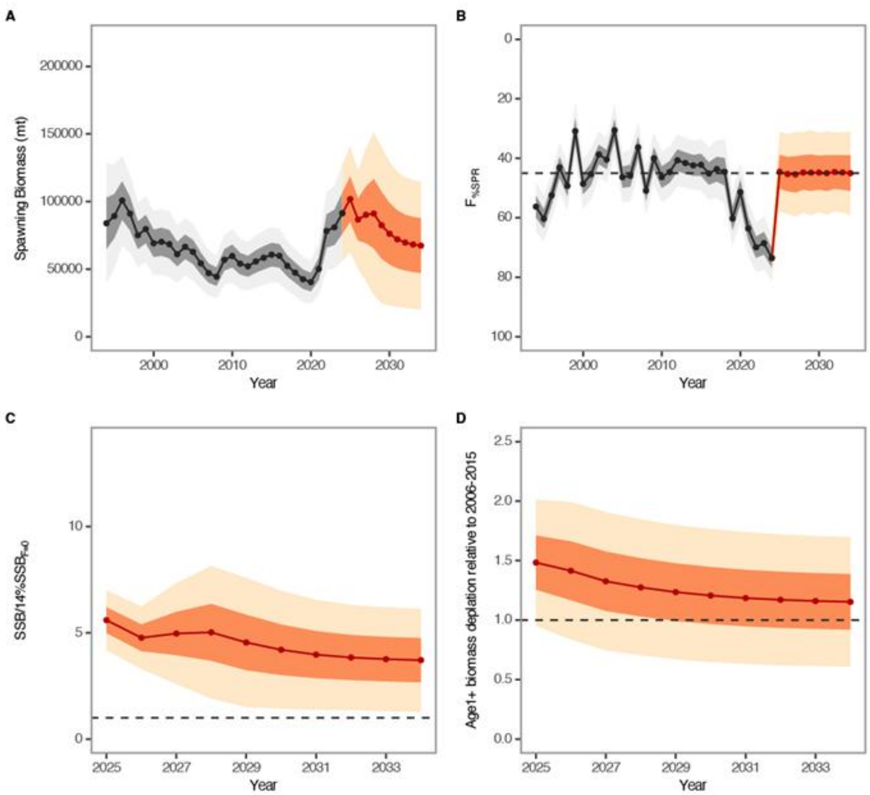


Figure A-11. Future projection results under a randomly F (2005-2019) scenario. Solid lines indicate mean values, and uncertainty ranges indicate 60% and 95% confidence intervals, and the dashed line is the reference point, respectively. (A) Annual changes in spawning biomass; (B) Interannual changes in fishing mortality (F%SPR); (C) Projected ratios to the limit reference point thresholds; and (D) Projected ratios to management targets for the total biomass. Figure 11.51 in stock assessment report.