INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

14TH MEETING

La Jolla, California (USA)
15-19 May 2023

DOCUMENT SAC-14 INF-R

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
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-at-age	Instantaneous fishing mortality at age
$F_{\%SPR}$	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
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.
SSB	Spawning Stock Biomass
USA	United States of America
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean

EXECUTIVE SUMMARY

Stock Identification and Distribution: The north Pacific albacore tuna (*Thunnus alalunga*) stock area consists of all waters in the Pacific Ocean north of the equator to 55°N. All available fishery data from this area were used for the stock assessment with a fleets-as-areas approach, under the assumption that there is instantaneous mixing of albacore on a quarterly basis, i.e., a single well-mixed stock.

Major changes from the 2020 assessment: There were four main changes to the base case model compared to the previous assessment in 2020. **1**) Increased uncertainty was imposed on the size composition and abundance index data for 2020 and 2021because fishery operations and data collection protocols were likely affected by COVID-19 safety protocols. **2**) Two JPLL fleets were further subdivided nominally into juvenile and adult fleets to improve model fits and diagnostics. **3**) A new adult abundance index was developed from the JPLL fleet in Area 2, Quarter 2 and used as the abundance index. **4**) Selectivity patterns for the two main JPPL fleets were modified to have only a single time block (2016 – 2021) due to model convergence issues. Sensitivity of results to the model structure changes listed above are illustrated with a model using a similar structure to the base case model in the 2020 assessment, albeit with the same data as this assessment (Table ES1).

Catches: During the modeling period (1994-2021), the total reported catch of north Pacific albacore reached a peak of about 119,000 t in 1999 and then declined in the early 2000s, followed by a recovery in later years. However, catches have dropped to low levels during two out of the last three years of the time series, with catches of about 43,000 t in 2019 and 2021 (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, and the USA) and non-member countries were compiled for the assessment. The fleet structure was similar to the 2020 assessment but an attempt was made to improve model fits and diagnostics by further subdividing the JPLL fleets operating in Areas 1 and 3 during Quarter 1 nominally into juvenile and adult fleets. Four relative abundance indices (standardized CPUE) were provided by Japan and the USA. 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 (F12 index; 1996 – 2021). This index was chosen because it represented the best information on trends for adult age-classes of female albacore, had good contrast, and ASPM analyses indicated the index was informative on both population trends and scale. Previous assessments 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 Quarter 2 CPUE.

The north Pacific albacore tuna stock was assessed using a length-based, age-, and sex-structured Stock Synthesis (SS; Version 3.30.21) model over the 1994-2021 period. Biological parameters like growth and natural mortality (M), were the same as for the 2017 and 2020 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 F12 index and all representative size composition data in a likelihood-based statistical framework. However, preliminary analyses indicated that fishery operations and data collection protocols in 2020 and 2021 were likely affected by COVID-19 safety protocols. Therefore, increased uncertainty was imposed on the size composition and abundance index data for those two years to reflect these effects. All but one fleet (USA longline) were assumed to have dome-shaped length selectivity patterns, and age-based selectivity for ages 1-5 were also estimated for surface fleets (primarily troll and pole-and-line) to address age-based changes in juvenile albacore availability and movement. Preliminary models with annually-varying age-selectivities for the two main JPPL fleets resulted in models without positive, definite Hessian matrices. However, models without any time varying age-selectivities matched the expected catch-at-age poorly and had poor ASPM diagnostics. Therefore, the ALBWG developed a model with a single age-selectivity time block for the two main JPPL fleets near the end of the historical period. This model adequately matched the catch-at-age and had good ASPM diagnostics. Selectivity patterns were also assumed to vary for fleets during periods consistent with important changes in fishing operations. 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 2017 and 2020 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, resulting in asymmetric uncertainty in the absolute scale of the stock, with more uncertainty in the upper limit of the stock than the lower limit. 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 HS 2022-01; IATTC Resolution C-22-04). 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. ES3A). Subsequently, the summary biomass fluctuated without a trend until 2018, after which the biomass rapidly increased to historically high levels. It should be noted that the high summary biomass estimates during 2018 – 2021 were highly uncertain and should be treated with caution (Fig. ES3A). These high summary biomass estimates were due to historically high recruitment estimates in 2017 (~432 million fish; 95% CI: 194 – 671 million fish) (Fig. ES3C). However, it should be noted that the recruitment estimates in the last 5 years (2017-2021) 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 2021 (Fig. ES3B).

The average fishing intensity during 2018 – 2020 was estimated to be $F59_{\%SPR}$ (95% CI: $F72_{\%SPR}$ – $F46_{\%SPR}$), which was relatively moderate and resulted in a population with an SPR of approximately 59%. 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 12 (Fig. ES4). Juvenile albacore aged 2 to 4 years comprised approximately 64% of the annual catch-at-age in numbers between 1994 and 2021 (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. ES7A; 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 (2021) estimates. However, the estimated fishing intensity for five years (1999, 2002, 2003, 2004, and 2007) have exceeded the target reference point. Even when alternative hypotheses about key model uncertainties such as growth were evaluated, the point estimate of female SSB in 2021 (SSB_{2021}) did not fall below the threshold and limit reference points, although the risk increases with this more extreme assumption (Fig. ES7B). However, estimated average fishing intensity during 2018-2020 ($F_{2018\text{-}2020}$) did exceed the target reference point under one of these alternative hypotheses but did not exceed the average fishing intensity during 2002 – 2004 (Fig. ES7B; Table ES1).

The SSB_{2021} was estimated to be approximately 54% (95% CI: 40 – 68%) of $SSB_{current,\ F=0}$ and 1.8 (95% CI: 1.3 – 2.3) times greater than the estimated threshold reference point (Table ES1). The estimated current fishing intensity ($F_{2018\text{-}2020}$) was estimated to be $F59_{\%SPR}$ (95% CI: $F72_{\%SPR}$ – $F46_{\%SPR}$) 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 likely not 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 likely not experiencing overfishing relative to the target reference point ($F45_{\%SPR}$).

Future Projections: The future projections for the 2023 stock assessment are currently still under development, and are not included in this preliminary document.

Conservation Information: The future projections for the 2023 stock assessment are currently still under development, and are not included in this preliminary document. Therefore, the conservation information for the 2023 stock assessment is currently unavailable.

Key Uncertainties: The ALBWG notes that the lack of sex-specific size data, uncertainty in growth and natural mortality, uncertainty in the impacts of COVID safety protocols on fishery operations and data collection, 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 WCPFC and IATTC for north Pacific albacore tuna included the identification of exceptional circumstances during the stock assessment. The ALBWG developed and considered the preliminary criteria for identifying exceptional circumstances for north Pacific albacore tuna, and did not find any strong evidence of exceptional circumstances with respect to the conservation and management of this stock. At this time, the ALBWG stresses that the preliminary criteria are still incomplete and without implementation indicators based on adopted HCRs, the application of these incomplete criteria may bias results and introduce uncertainty.

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) two important sensitivity models due to uncertainty in growth parameters; and 3) a model representing an update of the 2020 base case model to 2023 data. 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 2020 base case model is similar to but not identical to the 2020 base case model due to changes in data preparation and model structure. *Model may not have converged and uncertainty estimates were unreliable because of the lack of a positive, definite Hessian matrix. †A value of >1 for the depletion ratio indicates higher age-1+ biomass in 2021 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 CV = 0.06 for L_{inf}	Growth All parameters estimated	Update of 2020 base case model to 2023 data*
MSY (t)	121,880	93,167	144,792	97,777
SSB_{MSY} (t)	23,154	18,133	30,435	18,756
SSB_0 (t)	165,567	128,155	198,913	132,570
SSB_{2021} (t)	70,229	35,418	101,161	36,909
$SSB_{current, F=0}$ (2021 estimate)	129,581	97,368	155,542	93,808
$SSB_{2021}/SSB_{current, F=0}$	0.54	0.36	0.65	0.39
$SSB_{2021}/30\%SSB_{current, F=0}$	1.81	1.21	2.17	1.31
$SSB_{2021}/14\%SSB_{current, F=0}$	3.87	2.60	4.65	2.81
†$Depletion_{2021}/Depletion_{2006-2015}$	1.34	1.33	1.37	1.30
§ $F_{\%SPR, 2018-2020}$ (%SPR)	59.0	41.4	70.4	43.2
§ $F_{\%SPR, 2011-2020}$ (%SPR)	55.0	36.6	63.8	37.9
¶ $F_{\%SPR, 2018-2020}/F_{\%SPR, MSY}$	2.04	1.42	2.78	1.47
¶ $F_{\%SPR, 2011-2020}/F45_{\%SPR}$	1.22	0.81	1.42	0.84
¶ $F_{\%SPR, 2018-2020}/F45_{\%SPR}$	1.31	0.92	1.56	0.96
¶ $F_{\%SPR, 2018-2020}/F_{\%SPR, 2002-2004}$	1.48	1.63	1.40	1.25

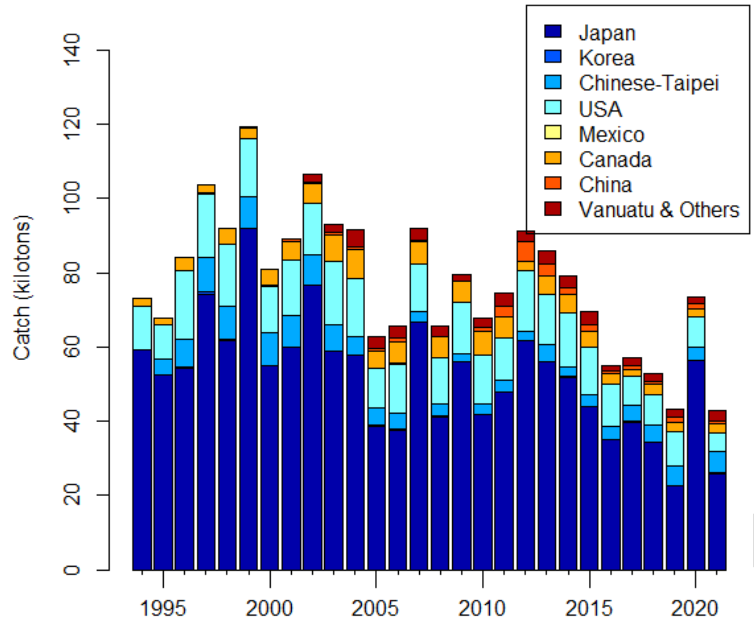

Figure ES1. Estimated total annual catch of north Pacific albacore (*Thunnus alalunga*) by all countries harvesting the stock, 1994-2021. Catches by Vanuatu and other countries includes small amount of catch by other countries such as Tonga, Belize, Cook Islands, and Marshall Islands.

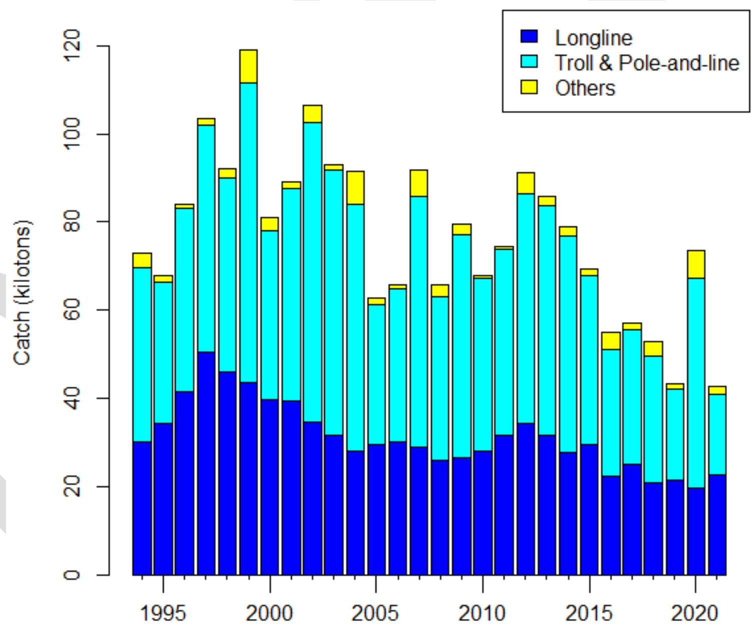

Figure ES2. Estimated catches of north Pacific albacore (*Thunnus alalunga*) by major gear types, 1994-2021. The Other gear category includes catches with purse seine, gillnet, hand lines, and harpoons.

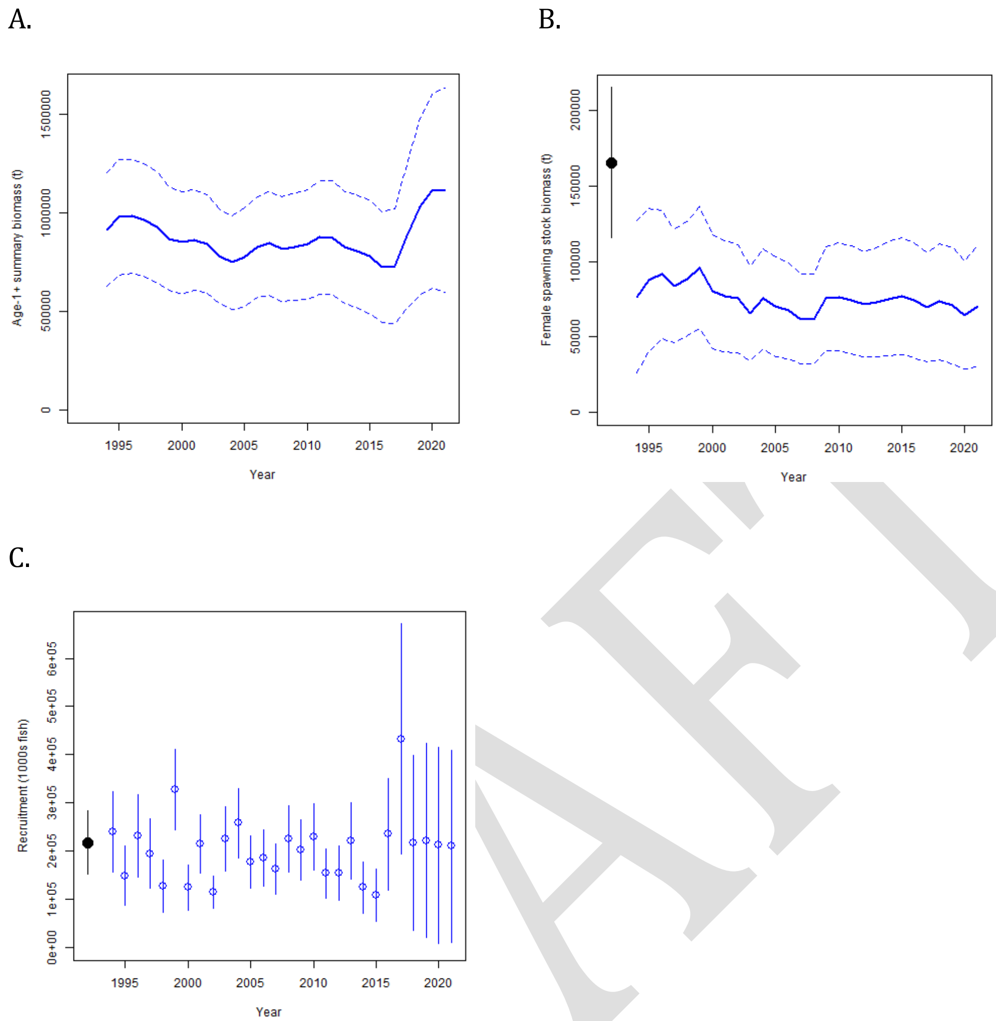

Figure ES3. Maximum likelihood estimates of (A) age-1+ biomass (B), female spawning biomass (SSB), and (C) age-0 recruitment of north Pacific albacore tuna (*Thunnus alalunga*). Dashed lines (A and B) and vertical bars (C) indicate 95% confidence intervals. Closed black circle and error bars in (B) and (C) are the maximum likelihood estimate and 95% confidence intervals of unfished female spawning biomass, SSB_0, and unfished recruitment, respectively, at equilibrium.

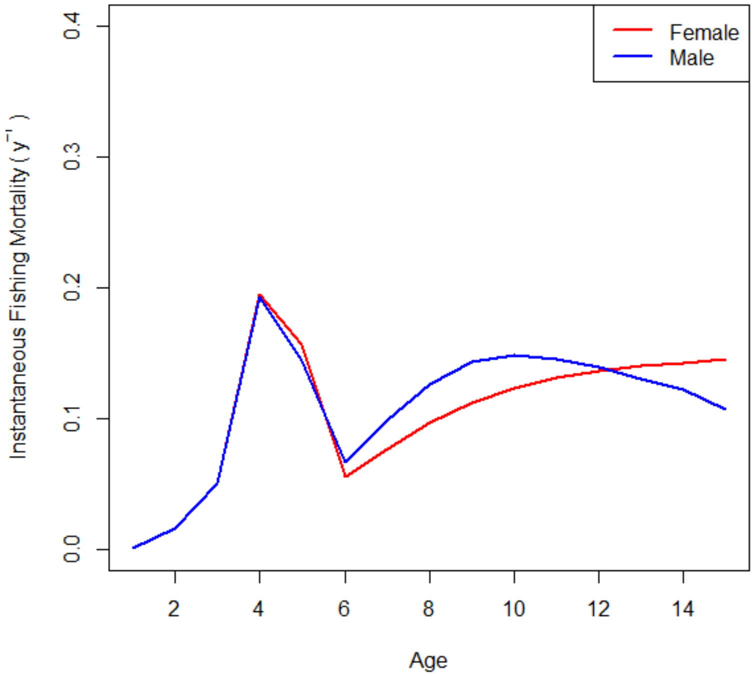

Figure ES4. Estimated sex-specific instantaneous fishing mortality-at-age (F-at-age) for the 2023 base case model, averaged across 2018-2020.

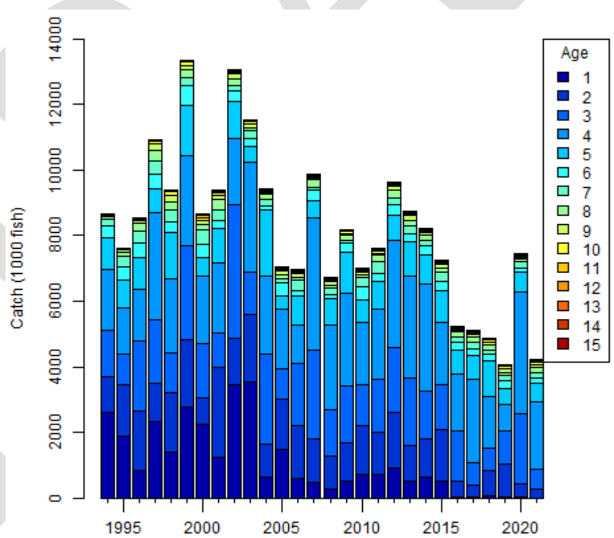

Figure ES5. Historical catch-at-age of north Pacific albacore (*Thunnus alalunga*) estimated by the 2023 base case model.

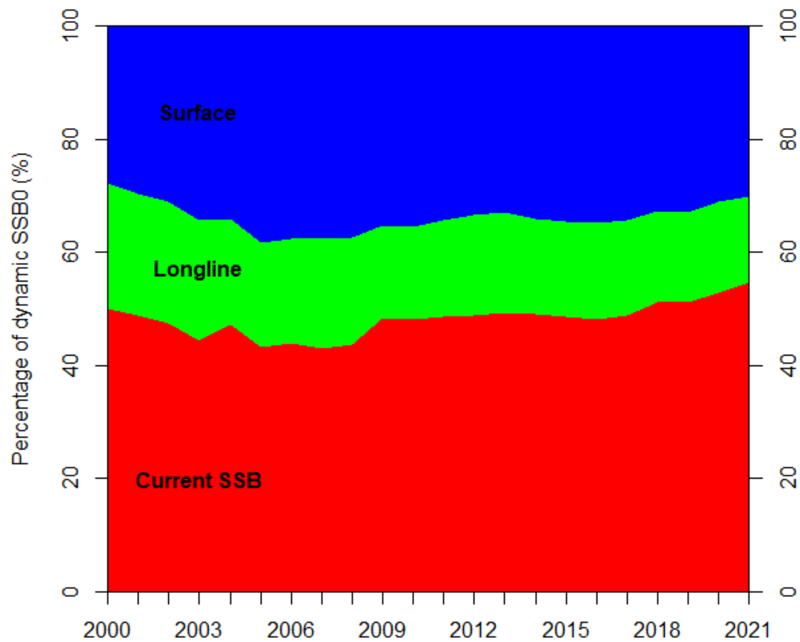

Figure ES6. Fishery impact analysis on north Pacific albacore (*Thunnus alalunga*) showing female spawning biomass (SSB) (red) estimated by the 2023 base case model as a percentage of dynamic, unfished female SSB ($SSB_{current, F=0}$). Colored areas show the relative proportion of fishing impact attributed to longline (green) and surface (blue) fisheries (primarily troll and pole-and-line gear, but including all other gears except longline).

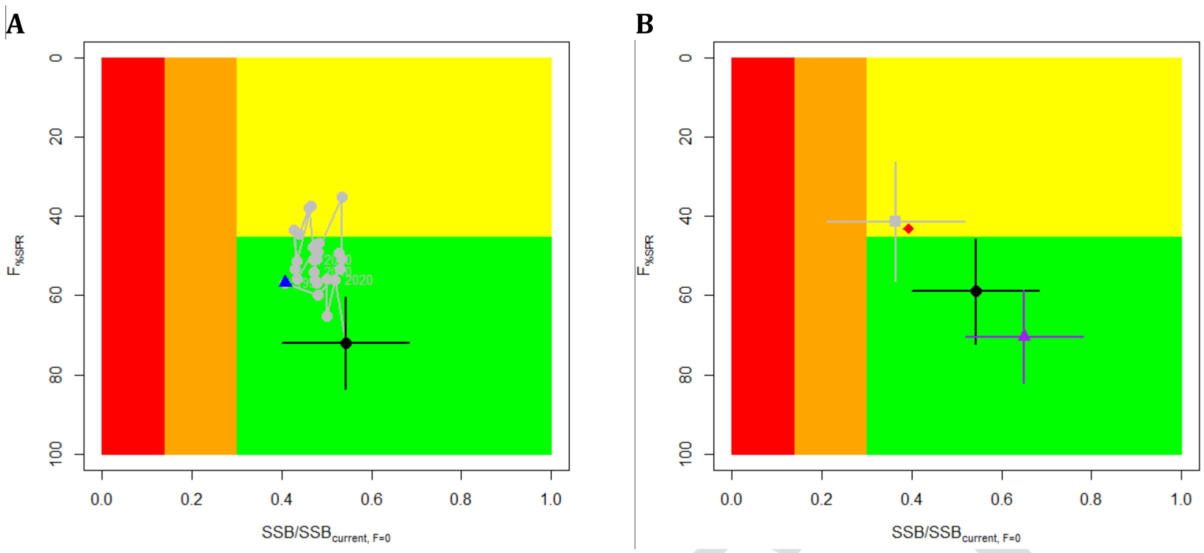

Figure ES7. (**A**) Stock status phase plot showing the status of the north Pacific albacore (*Thunnus alalunga*) stock relative to the biomass-based threshold (30%$SSB_{current,\ F=0}$) and limit (14%$SSB_{current,\ F=0}$) reference points, and fishing intensity-based target reference point ($F45_{\%SPR}$) over the modeling period (1994 – 2021). Blue triangle indicates the start year (1994) and black circle with 95% confidence intervals indicates the terminal year (2021). (**B**) Stock status plot showing current stock status and 95% confidence intervals of the base case model (black circle), an important sensitivity run of CV = 0.06 for L_{inf} in the growth model (gray square), an important sensitivity run with an estimated growth model (purple triangle), and a model representing an update of the 2020 base case model to 2023 data (red diamond). 95% confidence intervals are not shown for the update of the 2020 base case model (red diamond) because the model did not have a positive definite Hessian matrix and uncertainty estimates were unreliable. 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 2018-2020 ($F_{\%SPR,\ 2018\text{-}2020}$) and 2021 ($SSB_{2021}/SSB_{current,\ F=0}$), respectively. The model representing an update of the 2020 base case model is similar to but not identical to the 2020 base case model due to changes in data preparation and model structure.