ISC/19/ALBWG-01/03

Potential improvements to the stock assessment model for North Pacific albacore tuna[1]

Steven L. H. Teo[2],

Carolina Minte-Vera[3],

Desiree Tommasi[2]

[2]Southwest Fisheries Science Center,
NOAA Fisheries,
8901 La Jolla Shores Drive,
La Jolla, California 92037-1508, USA

[3]Inter-American Tropical Tuna Commission
8901 La Jolla Shores Drive
La Jolla, CA 92037-1509, USA

Email: steve.teo@noaa.gov

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

Abstract

In preparation for the upcoming stock assessment of North Pacific albacore tuna scheduled for 2020 by the Albacore Working Group, the 2017 base case model was re-examined and several potential improvements were identified. These improvements could be classified into two main groups: 1) **Group #1** improvements would maintain a relatively similar model structure to the 2017 base case model, with a start year of 1993; and 2) **Group #2** improvements are focused on extending the start year back to 1966, which is the start year used in the 2014 assessment. The suggested improvements can be summarized as: 1) Correcting catch errors; 2) updating to Stock Synthesis v3.30; 3) fitting to alternative abundance indices; 4) improving abundance indices; 5) reducing misfit to size composition data of major juvenile fisheries; 6) area-specific fleet definitions; 7) sex-specific size composition data from Japanese training and research vessels; 8) size composition data from China and Vanuatu longline fleets; and 9) extending model back to 1966. Based on the analyses of these suggested improvements, a non-exhaustive list of recommendations was developed for the Albacore Working Group to consider, in preparation for the 2020 assessment.

Introduction

The Albacore Working Group (ALBWG) of the International Scientific Committee for Tuna and Tuna-like species in the North Pacific Ocean (ISC) is responsible for conducting stock assessments of North Pacific albacore tuna (NPALB). The previous two assessments were conducted in 2014 and 2017. In preparation for the upcoming stock assessment of NPALB scheduled for 2020 by the ALBWG, we re-examined the 2017 base case model and identified several potential improvements, which could be classified into two main groups.

Potential improvements identified in **Group #1** would maintain a relatively similar model structure to the 2017 base case model, with a start year of 1993. It is therefore likely that these improvements can be more easily and successfully incorporated into the 2020 assessment. However, one drawback of starting the model in 1993 is that the population dynamics of the stock during 1975-1992, when the stock appeared to be experiencing a different environmental and/or biological regime, is not included. This drawback was not critical to the 2017 stock assessment because the primary objective of the assessment was to provide information on the current status of the stock. However, excluding the 1975-1992 period might lead to an underestimate of future variability in the population dynamics of NPALB and impact the management strategy evaluation (MSE) of the stock (Tommasi and Teo 2019).

Improvements in **Group #2** are therefore focused on extending the start year back to 1966, which is the start year used in the 2014 assessment. The primary problem with starting the model in 1966 is the poorly fit size composition data from the Japanese longline fleets in 1975 – 1992, which could not be fit with reasonable selectivity and growth parameters, were strongly influencing the estimated population dynamics of the stock. In the 2014 assessment, the size composition data during this period were separated into separate fleets and severely down-weighted in an attempt to reduce the influence of poorly-fit size composition data. Developing a model that starts in 1966 would be beneficial to the development of the MSE operating model by exploring the population dynamics of the stock under an apparently different environmental and/or biological regime.

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

Data and Model in the 2017 Assessment

The base case model of the 2017 assessment was a fully-integrated model implemented using the Stock Synthesis (v3.24ab) modelling platform and included fishery-specific catches, size composition, and abundance indices from 1993 to 2015 (ALBWG 2017).

Twenty-nine (29) fisheries 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 fisheries (Table 1). These fisheries consisted primarily of 23 longline fisheries from Japan (F1 – F15), USA (F19 & F20), Chinese-Taipei (F21 & F22), Korea (F23), China (F24 & F25), and Vanuatu (F26) (Table 3.1). There were also three pole-and-line fisheries from Japan (F16 – F18), and the surface gears (primarily troll and pole-and-line) from Canada, Mexico, and the USA, which were combined into a single surface gear fishery (F27). In addition, drift net catches from Japan, Korea, and Chinese-Taipei were combined into a single fishery (F28), which was important in the past but less so 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 fishery (F29). The approximate fishing area of each fishery can be deduced from Table 1 and Figure 1.

There were three major changes to the base case model compared to the previous assessment in 2014. Most importantly, a new procedure was used to standardize the Japanese longline abundance index (1996 – 2015) to indicate trends in adult albacore abundance and the results represent a substantial improvement relative to 2014 and earlier assessments. This new index had good contrast and, based on Age-Structured Production Model (ASPM) diagnostic analyses, informative on both population trend and scale. Secondly, the start year of the base case model was changed from 1966 (in 2014) to 1993 (in 2017). This change eliminated the influence of poorly fit size composition data from the Japanese longline fleets in 1975 – 1992, and eliminated the conflict between these size composition data and the primary adult albacore indices. Lastly, the instantaneous rate of natural mortality (M) was assumed to be 0.3 y-1 for both sexes at all ages for previous assessments. The basis for this assumption was reviewed and found to be poorly supported. 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+ males and females, respectively.

Sex-specific growth curves from the 2014 assessment were used because of evidence 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 assessment model was fitted to the primary adult index (F9 index) (1996-2015) and all representative size composition data in a likelihood-based statistical framework. All fleets were assumed to have dome-shaped length selectivity, and age-based selectivity for ages 1-5 was also estimated for surface fleets (troll and pole-and-line) to address age-based changes in juvenile albacore availability and movement. Selectivity was assumed to vary over time for fleets with important changes in fishing operations.

Group #1 improvements

Correcting catch errors for F11

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

The catch for F11 (F11_JPLL_A2_Q1_num) should have positive catch only in quarter 1. However, a visual inspection of the catch data showed that F11 included erroneous, duplicated catch from F12 (F12_JPLL_A2_Q234_num) in quarter 3. Removing this extraneous catch from F11 resulted in minor changes to the estimated female SSB time series (Fig. 2).

Updating to Stock Synthesis v3.30

For the 2020 assessment, it is recommended that the modeling framework be updated to the current version of Stock Synthesis (v3.30) to take advantage of several new features. A series of v3.30.13beta Stock Synthesis models were developed from the 2017 base case model (Fig. 3). The 2017 base case model was replicated and further improved by eliminating unnecessary parameters for sharing length selectivity and seasonal recruitment distribution. Henceforth, the base case model for the rest of this working paper is the v3.30.13beta version of the model with corrected catch and simplified recruitment and selectivity options (v3.30.13 simplify slx in Fig. 3).

Fitting to alternative abundance indices

Based on the size of fish caught by F1 (F1_JPLL_A13_Q1_wt), which are slightly smaller than caught by the primary adult index (F9), an abundance index based on F1 could be used to represent juvenile and/or sub-adult population trends. This option was not fully investigated during the 2017 assessment due to lack of time. Several preliminary indices were subsequently developed from the Japanese longline logbook data from Areas 1&3 (F1 index), Area 4 (F13 index) and Area 5 (F15 index) for the NPALB MSE, using similar methods to the primary adult index in the base case model.

Here, we fit to these new candidate indices to examine their impact on the model. Firstly, we use the F1 as a candidate juvenile/subadult index in the base case model using the same weighting as the F9 index (average CV=0.2) and found that the fit to the F1 index was reasonably good (Fig. 4), with an rmse of 0.232. The model fit to the primary adult index (F9) was improved (rmse: 0.156 vs 0.175; Fig. 5) but the overall fit to the size composition data degraded slightly (likelihood: 412.66 vs 408.96). This suggests that the F1 index is relatively consistent with the F9 index and may be a good candidate for inclusion in the 2020 assessment but more work will need to be done on developing and reviewing the index (see below).

In contrast, fitting to the Area 4 (F13 index) and/or Area 5 (F15 index) indices resulted in poorer fits to those indices (F13 rmse: 0.276; F15 rmse: 0.700). This suggests that fitting to the F15 index would not likely be beneficial to the 2020 assessment. However, further work on the F13 index may be warranted.

Fitting to these alternative indices resulted in slight changes to the estimated scale and trends of the female SSB (Fig. 8). Hereafter, the base case models in this investigation included fitting to the F1 index.

Improving abundance indices

A close examination of the primary adult index (F9 index) and the candidate juvenile and sub-adult index (F1 index) suggested several improvements could be made. Details on how these indices

---

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

were developed using the VAST library (Thorson and Barnett 2017, Thorson 2019) can be found in Kinoshita et al. (2017).

The primary adult index (F9 index) starts in 1996 even though there are logbook data from 1993, and the base case model starts in 1993. During the 2017 assessment, the start year of the F9 index was changed from 1993 to 1996 due to observed biases in the standardization model. For the 2020 assessment, it would be good to re-examine the F9 index and potentially start the model in 1993.

An additional concern with the F9 index is the potential mismatch in the season used to represent the index. The data for the F9 index appear to be based on all four seasons of data but selectivity of the index was assumed to be based on F9, which is a Q1 fishery (Table 1). It is recommended to re-examine this assumption. If the JPLL fishery in A2 is further separated into seasonal fleets (see below), it may be necessary to develop season-specific versions of the adult index. Adult NPALB are assumed to exhibit seasonal movements and the primary spawning season is Q2, with likely extension to Q3, it is likely that the adult NPALB are predominantly in the spawning area during these two seasons. On the other hand, juveniles and sub-adults may move into those areas during the cooler seasons. If the above hypothesis holds, it may be more appropriate to fit the adult indices during Q2 and possibly Q3. Based on a visual examination of the size composition data, the size data in A2 are relatively consistent in recent years but are relatively sparse and inconsistent in the earlier years (Fig. 9).

Similarly, for the candidate juvenile/sub-adult index (F1), there may also be a potential mismatch in seasonality. The current F1 index in Areas A1&3 is based on Q1 data because this is the period when the fishery targets albacore and the majority of catch occurs during this period. However, it may be valuable to re-examine the appropriate seasonality because if the adult population is primarily in A2 during Q2, the NPALB in A1 & 3 during Q2 may be more consistently sub-adult. It is also interesting that the size of fish caught by the JPLL fishery in A1 and A3 during Q2 appears to be slightly smaller and have a more consistent size composition than during Q1 (Fig. 10).

Overall, it is suggested that the adult and sub-adult indices be re-examined both during the standardization and also how they are used in the model, in particular paying attention to the seasonality of the index in relation to the purported seasonal movements of the stock. It may also be useful to integrate the size composition data in conjunction with the CPUE data (Kai et al. 2017) during the standardization process. This may allow the WG to develop a single adult abundance index for the entire stock instead for specific areas. However, doing so may result in the need to develop separate size composition data specifically for the abundance index, which would necessitate careful re-weighting of the data to minimize the effect of "double-dipping" the size composition data.

The WCPFC and IATTC have begun developing longline indices of tropical tunas using data from multiple nations and integrating into a single stock-wide index. Given the changing distribution of the Japan longline effort, especially in the EPO, it will likely be necessary in the future to use a similar approach for NPALB. Therefore, the WG can consider future workshops to do so.

<u>Reducing misfit to size composition data of major juvenile fisheries</u>

The fisheries with the largest catches of NPALB are the surface fisheries of Japan (F16 & F17) and the EPO (US & Canada; F27), which targets juvenile albacore. Given the large number of individuals removed from the population by these fisheries, it is important to fit the size compositions of these fisheries well.

---

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

However, the size compositions of these fleets, especially the JPPL fleets (F16 & F17) are highly variable with no seasonal nor inter-annual consistency in the peaks observed, and are poorly fit (Fig 11). It is therefore strongly suggested that the size composition data for the JPPL fleets be re-examined in detail to ensure that the size composition data are representative of the catch by these fleets.

If the size composition data for these fleets are considered representative of the removals, the model should aim to fit these size compositions better. One possible approach to fitting these size compositions better would be to allow the model substantially more flexibility in the selectivity of the fleets. Here, we separated the JPPL fleets into seasonal fleets, and allow the age selectivity of the two primary fishing seasons (Q2 & Q3) to vary inter-annually. This results in a substantially better fitting model to the size composition data (Fig. 11) at the cost of substantially increasing the number of parameters. There was slight improvements to the fit to the adult (F9) and sub-adult indices (F1).

Subsequently, we take this approach and extend it to the EPO surface fishery in Q3. In addition, we attempted to fit the size composition data of the JPLL fleets by developing separate seasonal fleets for them. Including all this model flexibility resulted in substantial differences in the estimated scale of female SSB (Fig. 12). The largest effect of estimated resulted from the improved fit of the JPPL fleets, and secondarily from the EPO fleet. However, the effect of the seasonal JPLL fleets on estimated scale was negligible.

Area-specific fleet definitions

Preliminary analysis of the longline size composition data prior to the 2017 assessment suggested that there were processes that resulted in different areas of the North Pacific Ocean having different but relatively consistent sex and size (age) compositions (Teo 2016; Ochi et al. 2016). Based on this analysis, the Japanese longline and pole-and-line fleets in the 2017 assessment were separated into area-specific fleets. However, the other fleets were not segregated into area-specific fleets. It would likely be beneficial to segregate the fleets into the area-specific fleets in the near future. Doing so would allow the WG to study and attempt to model the process that lead to the different sex and size compositions in different areas. In addition, it would help the continued development of the operational model for the NPALB MSE.

Sex-specific size composition data from Japanese training and research vessels

The sex-specific size composition data from Japanese training and research vessels indicate that the size and sex compositions in areas A2 (Fig. 13) and A4 (Fig. 14) are skewed towards males, especially in area A4, which is roughly consistent with our expectations based on the sex-specific differences in growth and natural mortality. However, the skewness towards males in area A4 is even larger than expected, which suggests that the sex-specific differences in growth and natural mortality may be larger than previously expected or there are some processes that have not been included in the model (e.g., sex-specific movements and/or selectivity). Although the sex-specific composition data were made available during the 2017 assessment, the WG did not have time to evaluate the data and therefore did not include the data for the assessment. It would be highly beneficial for the WG to review the data and investigate the use of the data in the 2020 assessment.

Size composition data from China and Vanuatu longline fleets

Size composition data from China and Vanuatu were made available for the 2017 assessment by the IATTC and WCPFC, and were included as candidate data. However, the data were not fit in the

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

model because the size composition data were not raised to the catch and the WG did not review the data before the assessment. Instead, the selectivity of these fleets were mirrored to a fleet in the same area and using similar gear. Expected size compositions were visually compared to observations during the 2017 assessment and found to be reasonable. It would be beneficial if a WG member could take on the task of investigating these data, raising the data to the catch, documenting the data, and submitting it to the WG for review.

Group #2 improvements

Extending model back to 1966

The primary problem with starting the model in 1966 is the poorly fit size composition data from the Japanese longline fleets in 1975 – 1992 (Fig. 15). The size composition data could not be fit with reasonable selectivity (Fig. 16) and growth parameters. However, the misfit to the data were strongly influencing the estimated population dynamics of the stock. In addition, there was apparent conflict between these size composition data and the primary adult albacore indices. Developing a model that starts in 1966 would also be beneficial to the development of the MSE operating model by exploring the population dynamics of the stock under an apparently different environmental and/or biological regime.

We suggest that the size composition data for the JPLL fleets during the 1975-1992 period be re-examined in detail to ensure that the size composition data are representative of the catch by these fleets. If the size composition data for these fleets are considered representative of the removals, the model should aim to fit these size compositions better. In addition, it would be useful to look for complementary data sources like otolith archives or research vessel data from this period. Possible model processes to consider would include, time-varying sex-specific growth, natural mortality, selectivity.

Recommendations

Based on the above analyses, we have developed a non-exhaustive of recommendations for the WG to consider for the 2020 assessment:

1) Correct any catch errors;
2) Update modelling platform to v3.30 of Stock Synthesis;
3) Determine the appropriate seasonality for the adult (JPLL in A2) and juvenile/subadult (JPLL in A1&3) indices;
4) Develop adult and juvenile/subadult indices to be consistent with #3, and for 1993 – 2018;
5) Consider fitting to an index representing juveniles/subadults in area A1&3;
6) Consider further developing and fitting to an index representing adults in area A4;
7) Perform research on integrating size compositions with the CPUE data during the standardization process to produce a single stock-wide adult NPALB index;
8) Discuss holding a workshop to develop a combined fleets longline abundance index using methods developed in #7;

[1] This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

9) Re-examine the representativeness of the size composition data from the Japan pole-and-line and EPO surface fleets;
10) Consider area-specific fleets for all fisheries;
11) Develop and document area- and sex-specific size compositions from Japan research and training vessels;
12) Develop and examine models that fit to the sex-specific size compositions from #11 to estimate sex-specific differences in biology;
13) Develop and document area-specific size composition and other fishery data for China and Vanuatu longline fleets;
14) Re-examine the representativeness of the size composition data from the Japan longline vessels during 1975 – 1992 period;
15) Examine information on NPALB biology and fishery operations during the 1975 – 1992 period.

References

ALBWG. 2017. Stock assessment of albacore tuna in the North Pacific Ocean in 2017. Annex 12. Report of the 17th Meeting of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean Plenary Session, 12-17 July, 2017, Vancouver, Ca. Available from http://isc.fra.go.jp/pdf/ISC17/ISC17_Annex12-Stock_Assessment_of_Albacore_Tuna_in_the_North_Pacific_Ocean_in_2017.pdf.

Kai, M., Thorson, J.T., Piner, K.R., and Maunder, M.N. 2017. Spatiotemporal variation in size-structured populations using fishery data: an application to shortfin mako (Isurus oxyrinchus) in the Pacific Ocean . Can. J. Fish. Aquat. Sci. doi:10.1139/cjfas-2016-0327.

Kinoshita, J., Ochi, D., and Kiyofuji, H. 2017. Revised of standardized CPUE for North Pacific albacore caught by the Japanese pole and line data from 1972 to 2015. ISC/17/ALBWG/05. Work. Doc. Submitt. to ISC Albacore Work. Gr. Meet. 11-19 April 2017, Southwest Fish. Sci. Center, La Jolla, California, USA.

Thorson, J.T. 2019. Guidance for decisions using the Vector Autoregressive Spatio-Temporal (VAST) package in stock, ecosystem, habitat and climate assessments. Fish. Res. doi:10.1016/j.fishres.2018.10.013.

Thorson, J.T., and Barnett, L.A.K. 2017. Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. ICES J. Mar. Sci. doi:10.1093/icesjms/fsw193.

Tommasi, D., and Teo, S.L.H. 2019. Summary of results for the North Pacific albacore tuna (*Thunnus alalunga*) management strategy evaluation. ISC/19/ALBWG-01/?? Work. Doc. Submitt. to ISC Albacore Work. Gr. Meet. 26 February-4 March 2019, Natl. Res. Inst. Far Seas Fish. Shizuoka, Japan.

---

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

Table 1. Fishery definitions for the 2017 assessment of north Pacific albacore tuna. Availability of size and abundance index data are 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.

ID	Fishery name	Area	Primary gear	Quarter	Catch unit	Notes
F1	F1_JPLL_A13_Q1_wt	1 & 3	Longline	1	Tonnes	Size
F2	F2_JPLL_A13_Q2_wt	1 & 3	Longline	2	Tonnes	Size
F3	F3_JPLL_A13_Q3_wt	1 & 3	Longline	3	Tonnes	Size
F4	F4_JPLL_A13_Q4_wt	1 & 3	Longline	4	Tonnes	Size
F5	F5_JPLL_A13_Q1_num	1 & 3	Longline	1	1000s	
F6	F6_JPLL_A13_Q2_num	1 & 3	Longline	2	1000s	
F7	F7_JPLL_A13_Q3_num	1 & 3	Longline	3	1000s	
F8	F8_JPLL_A13_Q4_num	1 & 3	Longline	4	1000s	
F9	F9_JPLL_A2_Q1_wt	2	Longline	1	Tonnes	Size, Index
F10	F10_JPLL_A2_Q234_wt	2	Longline	2, 3 & 4	Tonnes	Size
F11	F11_JPLL_A2_Q1_num	2	Longline	1	1000s	
F12	F12_JPLL_A2_Q234_num	2	Longline	2, 3 & 4	1000s	
F13	F13_JPLL_A4_wt	4	Longline	All	Tonnes	Size
F14	F14_JPLL_A4_num	4	Longline	All	1000s	
F15	F15_JPLL_A5_num	5	Longline	All	1000s	Size
F16	F16_JPPL_A3_Q12	3	Pole & line	1 & 2	Tonnes	Size
F17	F17_JPPL_A3_Q34	3	Pole & line	3 & 4	Tonnes	Size, Index*
F18	F18_JPPL_A2	2	Pole & line	All	Tonnes	Size
F19	F19_USLL_A35	3 & 5	Longline	All	Tonnes	Size
F20	F20_USLL_A24	2 & 4	Longline	All	Tonnes	Size
F21	F21_TWLL_A35	3 & 5	Longline	All	Tonnes	Size
F22	F22_TWLL_A24	2 & 4	Longline	All	Tonnes	
F23	F23_KRLL	All	Longline	All	Tonnes	Size*
F24	F24_CNLL_A35	3 & 5	Longline	All	Tonnes	
F25	F25_CNLL_A24	2 & 4	Longline	All	Tonnes	Size*
F26	F26_VULL	All	Longline	All	Tonnes	Size*
F27	F27_EPOSF	3 & 5	Surface	All	Tonnes	Size
F28	F28_JPKRTW_DN	All	Drift net	All	Tonnes	
F29	F29_JPTW_MISC	All	Misc	All	Tonnes	

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

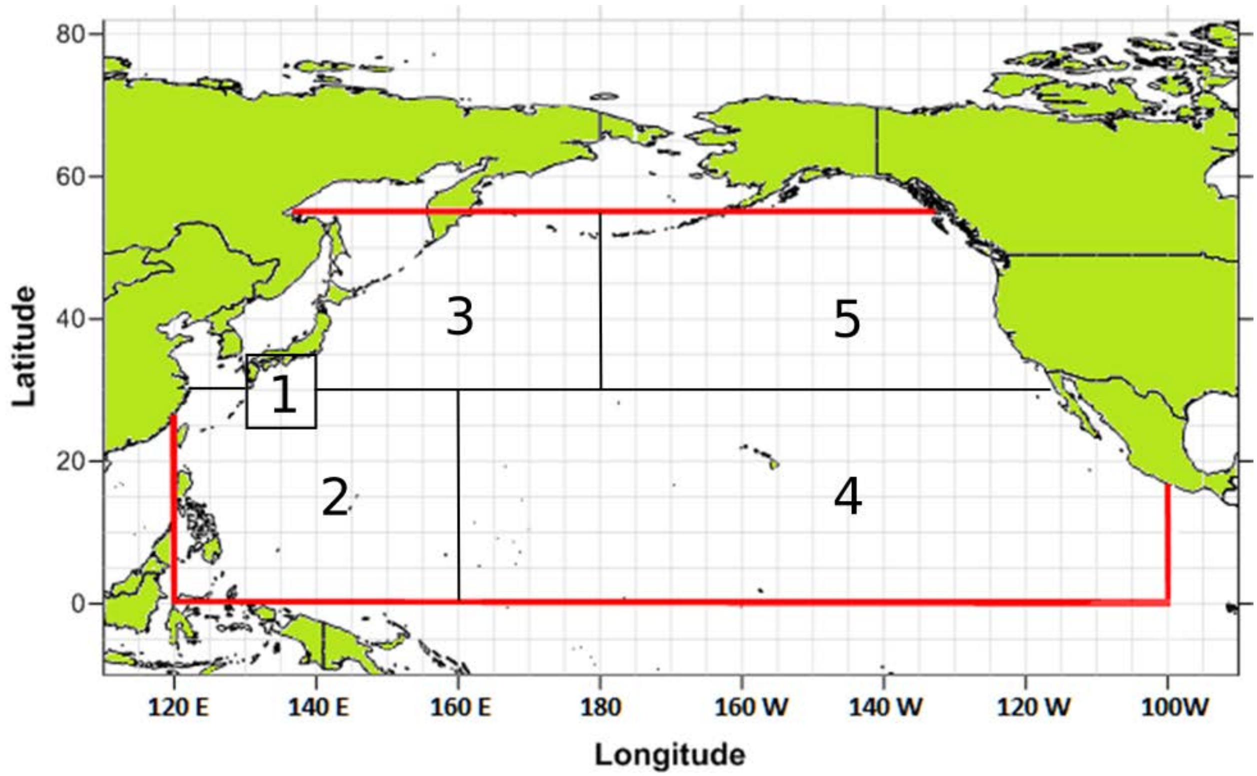

Figure 1. Spatial domain (red box) of the north Pacific albacore stock (*Thunnus alalunga*) in the 2017 stock assessment. Fishery definitions were based on five fishing areas (black boxes and numbers) defined from cluster analyses of size composition data.

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

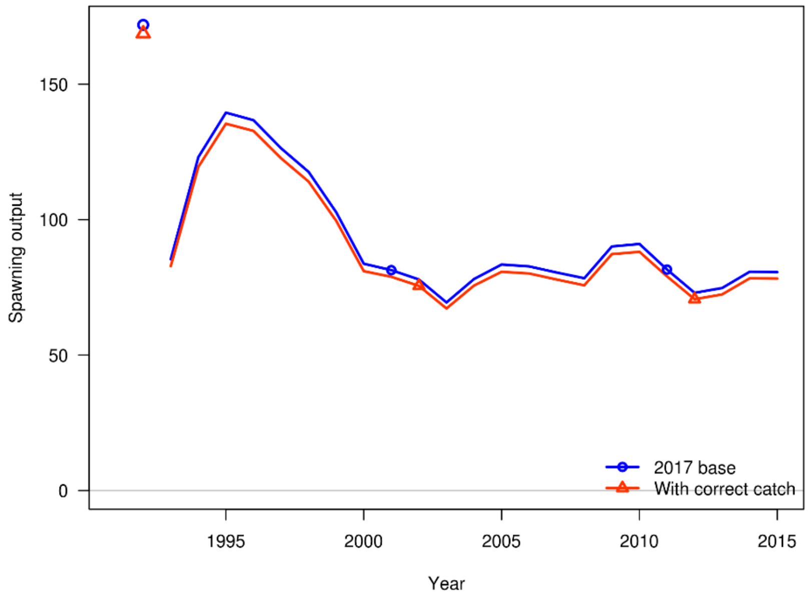

Figure 2. Comparison of estimated female spawning stock biomass of the 2017 base case model with a model containing a corrected time series of F11 catch.

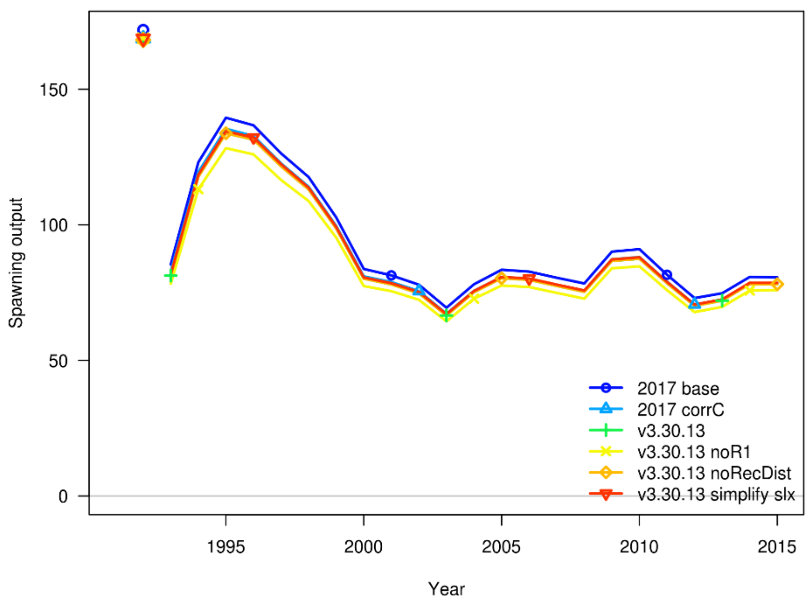

Figure 3. Comparison of estimated female spawning stock biomass of the 2017 base case model using v3.24AB (2017 base); a model containing a corrected time series of F11 catch (2017 corrC); v3.30.13 version of the 2017 base case model (v.30.13). The model was further improved by eliminating unnecessary parameters for seasonal recruitment distribution (noRecDist) and sharing length selectivity (simplify slx).

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

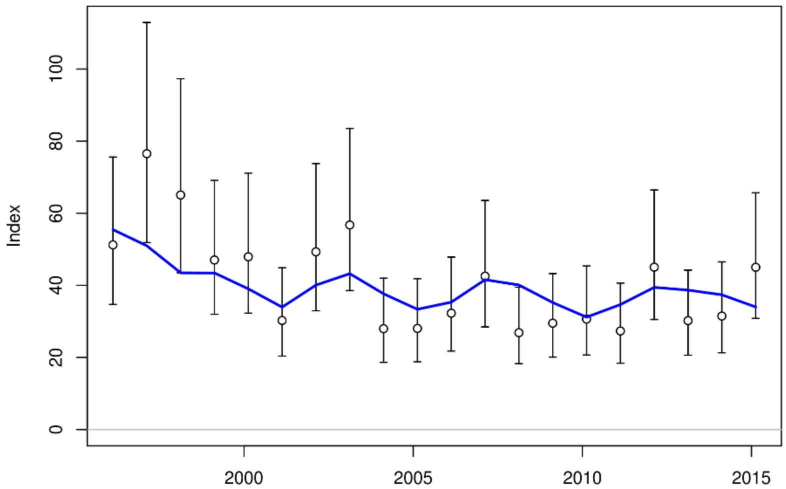

Figure 4. Fit of the preliminary F1 index (JPLL A13) to the base case model, when including the F1 index in the model fit. The primary adult abundance index (F9) is always fit.

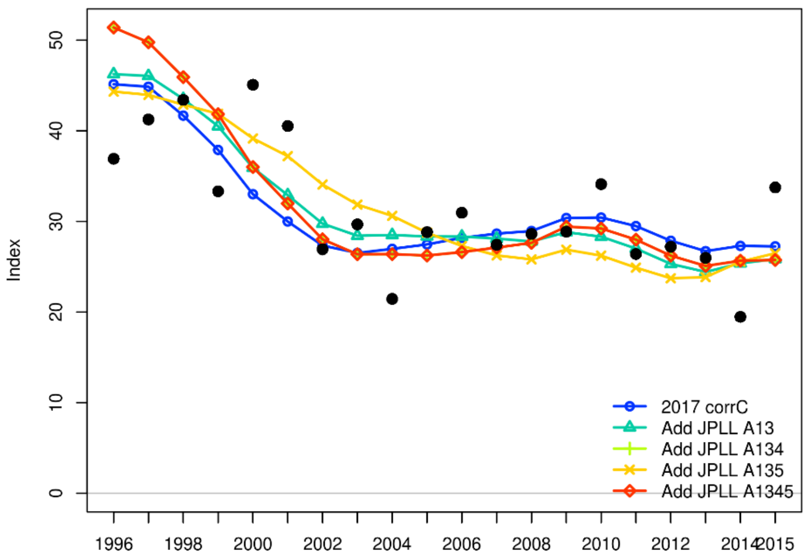

Figure 5. Model fit to the primary adult abundance index in: 1) 2017 base case model (corrC); 2) additionally fit the F1 index (JPLL A13); 3) fit the F1 and F13 indices (JPLL A134); 4) fit the F1 and F15 indices (JPLL A135); and 5) fit the F1, F13 and F15 indices (JPLL A135)

---

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

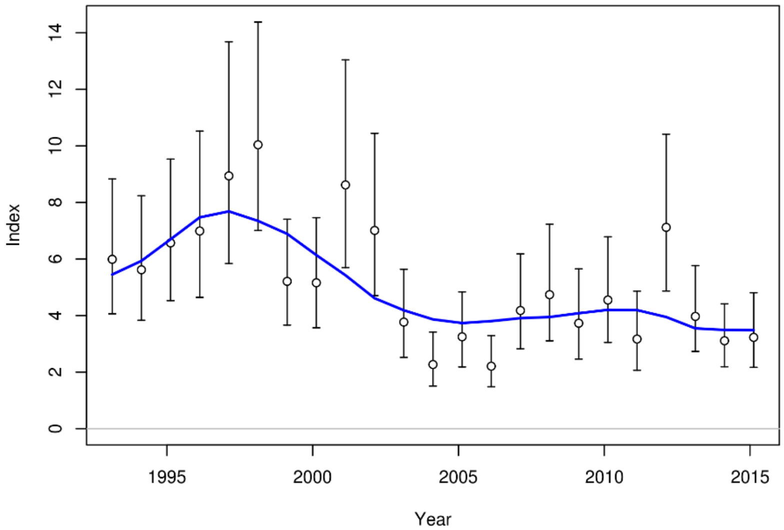

Figure 6. Fit of the preliminary the F13 index (JPLL A4) to the base case model, when including both the F1 and F13 indices to the model fit. The primary adult abundance index (F9) is always fit.

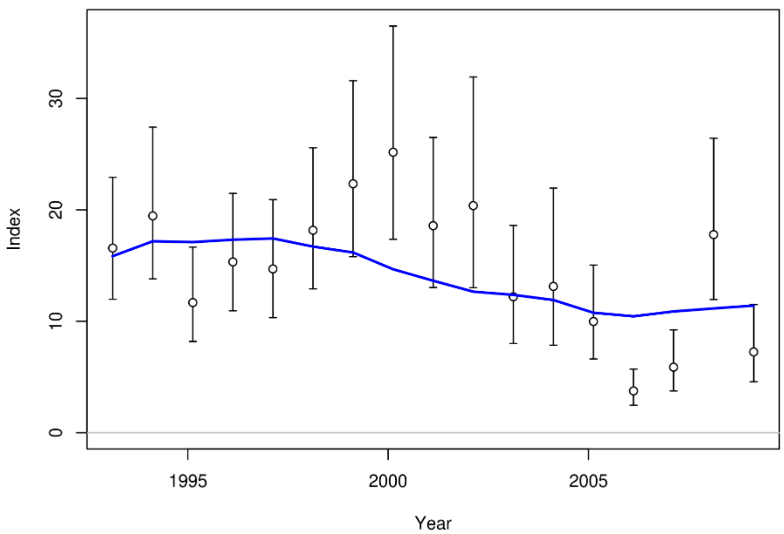

Figure 7. Fit of the preliminary the F15 index (JPLL A5) to the base case model, when including both the F1 and F15 indices to the model fit. The primary adult abundance index (F9) is always fit.

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

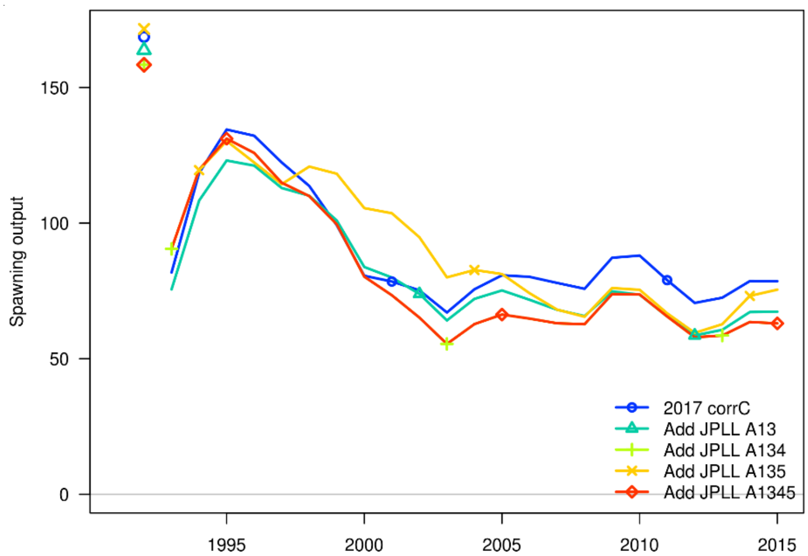

Figure 8. Comparison of female spawning stock biomass of: 1) 2017 base case model (corrC); 2) additionally fit the F1 index (JPLL A13); 3) fit the F1 and F13 indices (JPLL A134); 4) fit the F1 and F15 indices (JPLL A135); and 5) fit the F1, F13 and F15 indices (JPLL A135).

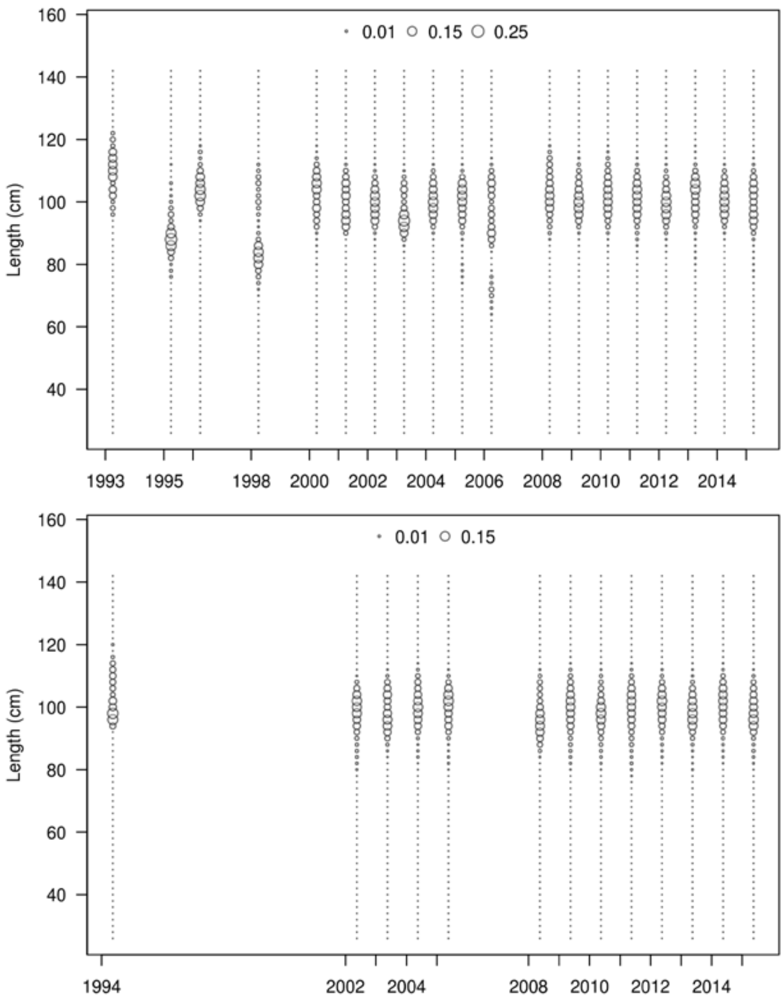

Figure 9. Observed size composition data for F10 during Q2 (upper) and Q3 (lower).

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

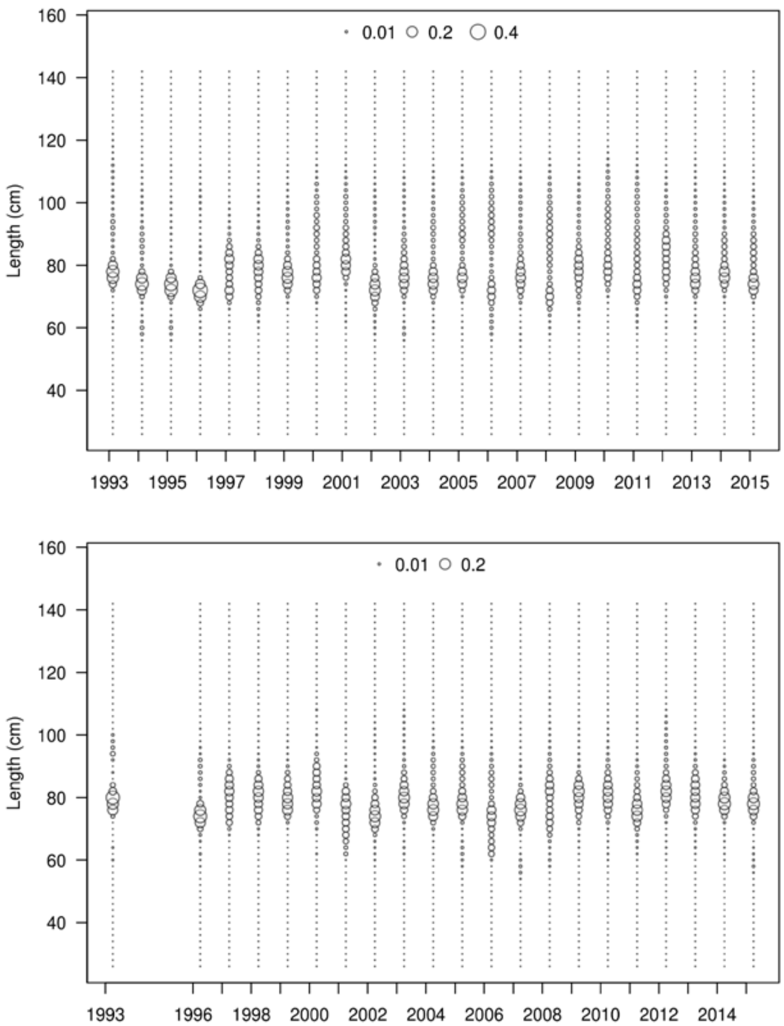

Figure 10. Observed size composition data for JPLL in areas A1&3 during Q1 (upper) and Q2 (lower).

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

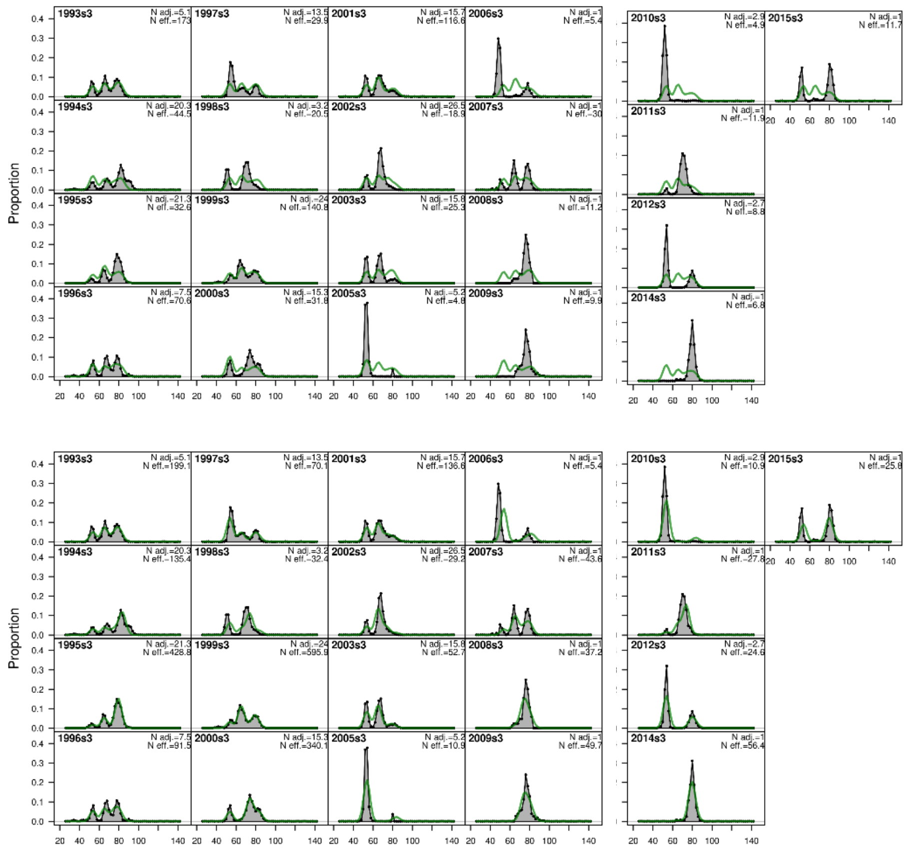

Figure 11. Model fit (green lines) to observed size composition data for JPPL in area A3 during Q3, in the base case model (upper) and when the fleet is separated into seasonal fleets and inter-annual variability of age-selectivity for the fleet is used.

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

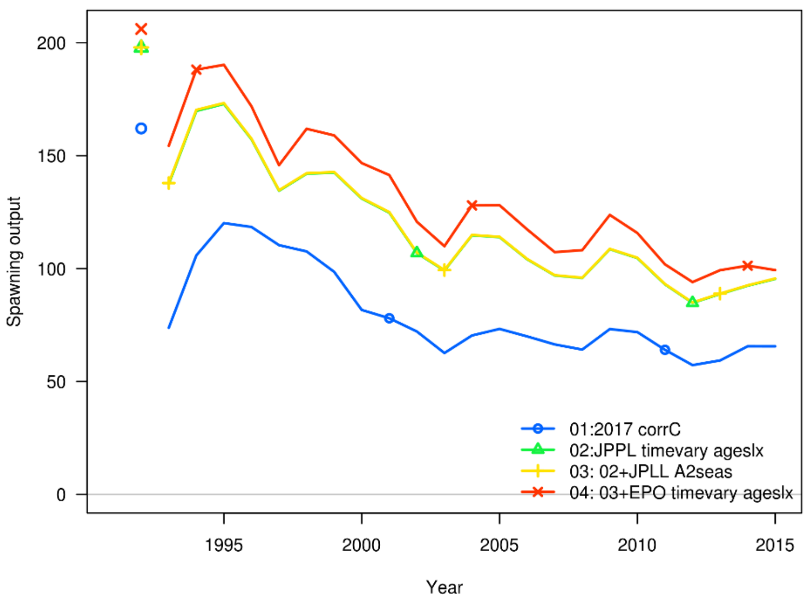

Figure 12. Comparison of female spawning stock biomass of: 1) 2017 base case model (corrC); 2) seasonal and time-varying selectivity for the JPPL fleets during Q2 & Q3 (JPPL timevary ageslx); 3) 02 plus seasonal JPLL fleets in area A2; and 4) 03 plus timevarying age selectivity for the EPO surface fleet.

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

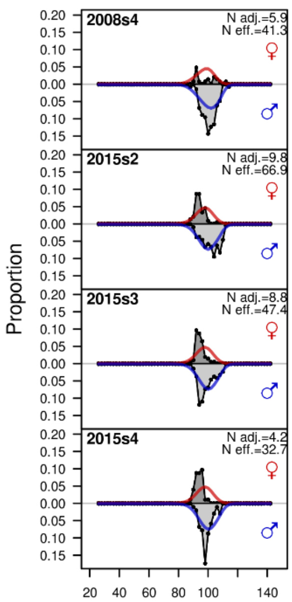

Figure 13. Observed sex-specific size composition data from JP research and training vessels in A2 during Q234. Data were not fit but red and blue lines indicate expected compositions.

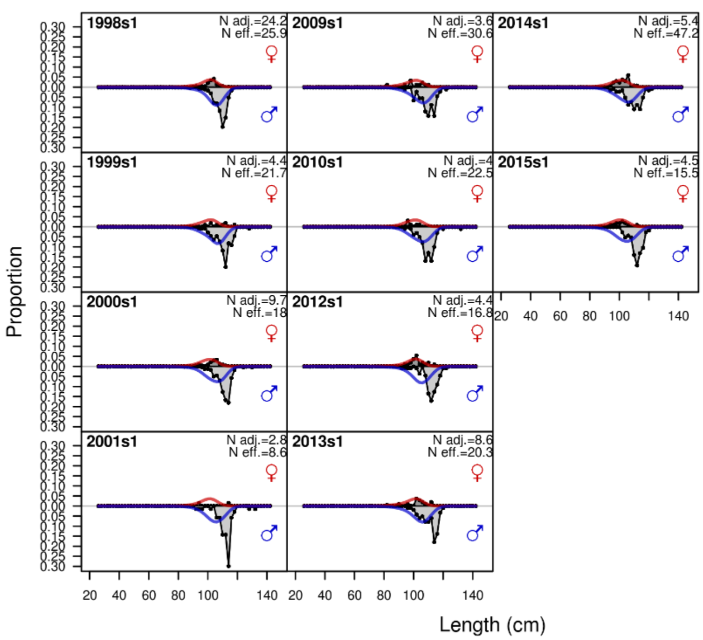

Figure 14. Observed sex-specific size composition data from JP research and training vessels in A4 during Q1234. Data were not fit but red and blue lines indicate expected compositions.

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

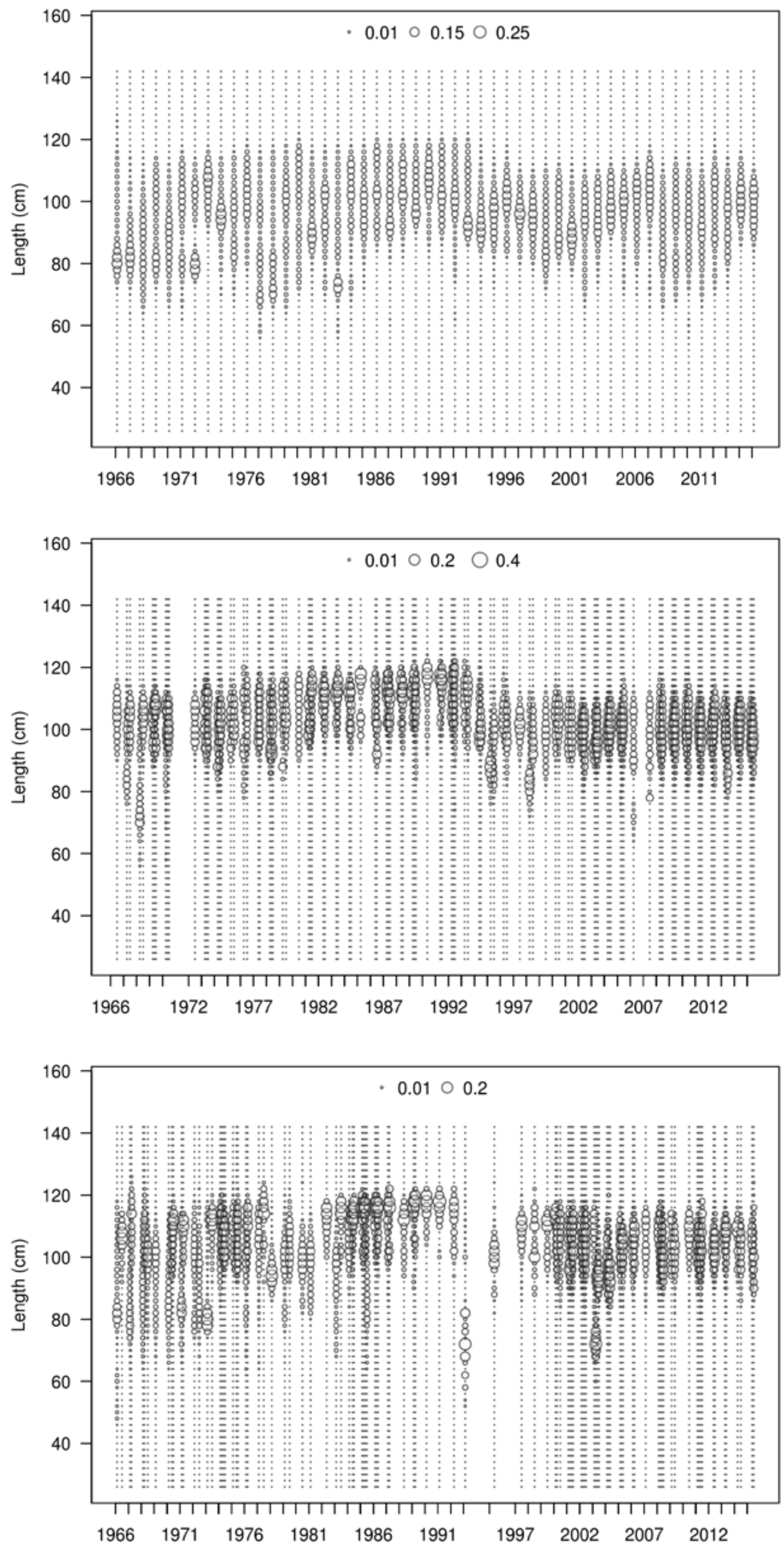

Figure 15. Observed size composition data from the JPLL fleets in A2 Q1 (upper), A2 Q234 (middle), and A4 Q1234 (lower) from 1966 to 2015.

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.

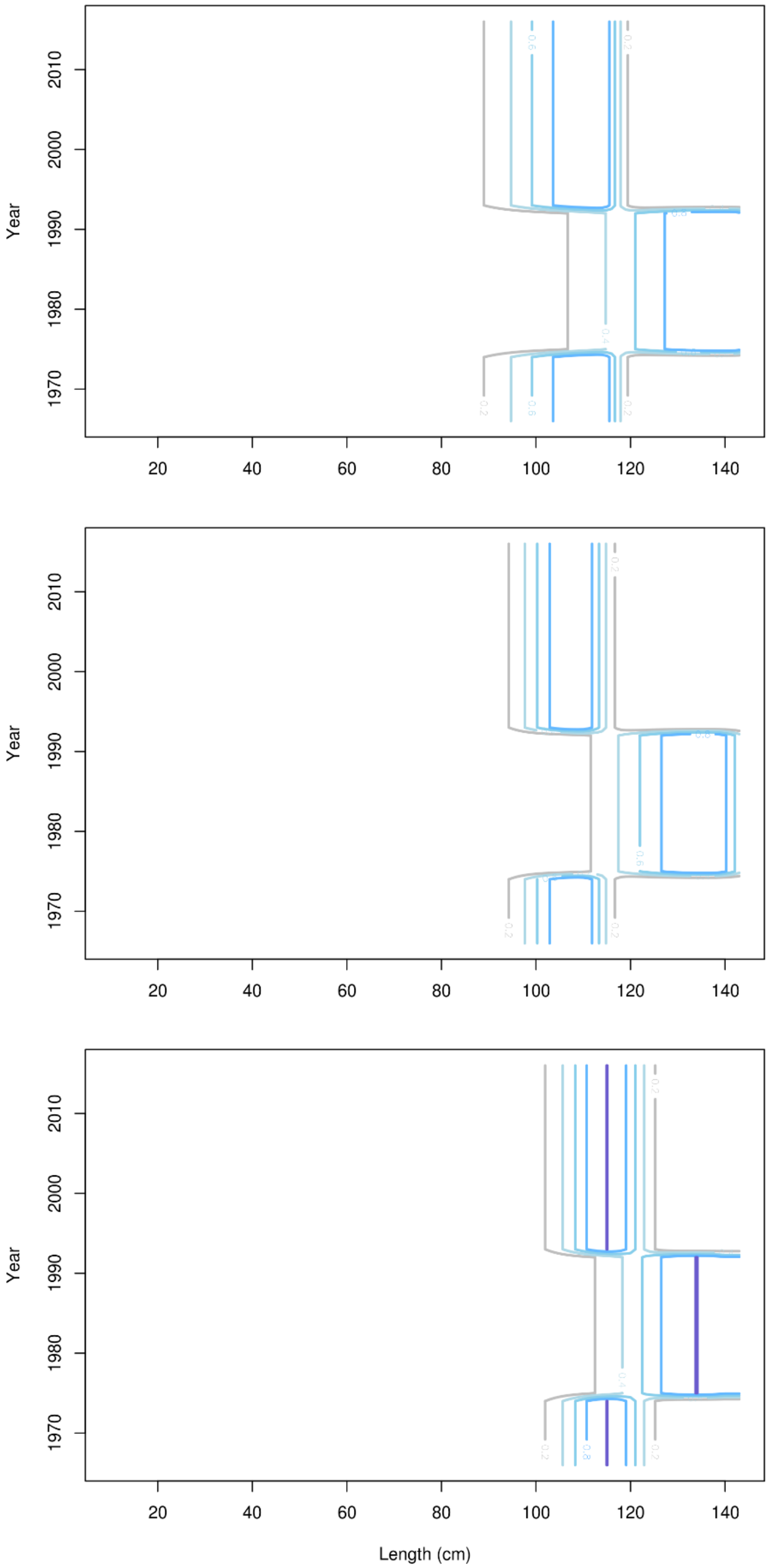

Figure 16. Estimated size selectivity for the JPLL fleets in A2 Q1 (upper), A2 Q234 (middle), and A4 Q1234 (lower) from 1966 to 2015.

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 26 February - 5 March 2019, held at the NRIFSF/FRA, Shimizu, Shizuoka, JAPAN. Document not to be cited without the author's permission.