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Standardized CPUE and size for North Pacific Albacore by Japanese Longline using VAST package

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Summary

This study provides information on the updated Japanese longline CPUE and the associated length composition. To examine the index of abundance used for the stock assessment, we standardized the CPUE from Japanese longline logbook data using the VAST package. Similar to the previous CPUE using the INLA model, we could observe a sharp decline around 2020 in the standardized CPUE from the VAST model. We re-examined the following hypotheses regarding the sharp decline in area 2's CPUE in 2020.

- COVID-19 impacted fishing operations – last year's document (ISC/24/ALBWG-01/02) did not support this hypothesis.
- Albacore moves to area 2 not in the first quarter of 2020 – the quarterly model for Area 2 did not support this hypothesis because the index was low in adjacent quarters as well.
- Albacore moves out of area 2 in the first quarter of 2020 – the center of biomass plot and the comparison of indices based on area 2 and area 2 + northern area (latitude 30–40°N, longitude 140–160°E) both support this hypothesis.

Additionally, the length compositions for the index of abundance was calculated successfully, which expected to help avoid conflicts between standardized CPUE and LF when inputting data into the stock assessment model.

Introduction

In the stock assessment of albacore (*Thunnus alalunga*) in the North Pacific, the Japanese longline CPUE has been used as an index representing the biomass of adult albacore (ALBWG, 2023a). In the past albacore working groups (ALBWG), the distribution of adult albacore was defined (Ijima et al., 2017), and the standardized CPUE of adult albacore was calculated using only Area 2, where adult albacore are predominantly distributed (Matsubayashi et al., 2023; Nishimoto et al., 2024). However, spatial filtering may render the CPUE unsuitable as an index of adult albacore if their distribution changes over time. Applying such CPUE to the stock assessment model can lead to conflicts between CPUE and size data for adult albacore.

In the previous working group meeting, a method was proposed to avoid the influence of temporally changes in adult distribution. Instead of spatial filtering, a finite-mixture model was used to extract adult albacore data based on size data (eye fork length) recorded in catch reports (Ijima et al., 2023; Matsubara et al., 2024a). If adult data can be accurately extracted from the fishery data using this method, the CPUE and size data will fit more consistently within the stock assessment model. Additionally, another approach reported by the IATTC was proposed during the previous ALBWG meeting (Maunder et al., 2020; IATTC, 2023). The IATTC approach first estimates standardized CPUE and standardized size, then calculate survey length composition by the standardized size weighted by the standardized CPUE (**Figure 1**). This method has the advantage of minimizing conflicts between CPUE and size data when incorporated into the stock assessment model. Consequently, one of the tasks for the 2025 albacore working group is to compare these CPUE estimation approaches and determine which approach to adopt for the 2026 stock assessment (ALBWG, 2024).

Another key task of the working group before the last meeting was to investigate the factors contributing to the decline in the adult index in 2020 (ALBWG, 2023b). The year 2020 marked the onset of the COVID-19 pandemic, during which various restrictions were imposed on human activities. Given the potential impacts of these restrictions on also fisheries, the previous working group examined whether the decline in the CPUE index was influenced by COVID-19 (Matsubara et al., 2024b). This document indicated that the fishing effort in 2020 was similar to that of recent years. Additionally, a questionary survey to longline fishers revealed that their fishing locations and operations remained unchanged before and after the pandemic. Therefore, the decline in the 2020 CPUE index was concluded to be unrelated to the effects of COVID-19. Furthermore, an analysis of the spatial distribution of nominal CPUE in longline fisheries showed higher CPUE values north of Area 2, suggesting that albacore were distributed further north than in previous years. However, the spatial distribution of standardized CPUE was not examined, and it remained unclear whether standardized CPUE—accounting for spatiotemporal and vessel effects—also supports the northward shift of albacore distribution.

This document follows the IATTC approach to provide information on standardized CPUE and survey length composition and further investigates the causes of the CPUE decline in 2020. First, a VAST model was used to estimate standardized CPUE while accounting for spatial and spatiotemporal effects. To examine whether the northward shift in albacore distribution contributed to the CPUE decline, CPUE trends around 2020 were compared between an index based only on Area 2 and an index incorporating both Area 2 and the northern area (latitude 30–40°N, longitude 140–160°E).

Next, standardized size estimates were obtained using the same spatiotemporal framework as standardized CPUE. Finally, survey length composition was generated by weighting the standardized size by standardized CPUE across different spatiotemporal strata, and the resulting distribution was compared with the original size data distribution.

Data and methods

CPUE standardization

To estimate standardized CPUE, we used the Japanese longline logbook data from 1994 to 2023. The Japanese longline logbook includes information such as year, month, day, and fishing location (latitude and longitude, 1-minutes resolution). Additionally, it contains details on gear configuration, including the number of hooks, the length of main and branch line, and the number of hooks between floats (HBF). Given that Area 2 has been reported as the primary habitat of adult albacore (Ijima et al., 2017) and that the main fishing season for albacore occurs in Quarter 1, we extracted data from Area 2 for Quarter 1 for calculating adult albacore CPUE. Following the data aggregation methods used in previous CPUE estimations (Matsubayashi et al., 2023; Nishimoto et al., 2024), the logbook data were aggregated based on year, quarter (only applicable when calculating Quarterly CPUE, later), latitude and longitude (1-degree resolution), vessel name, and HBF.

For CPUE standardization, we followed the IATTC approach (Maunder et al., 2020; IATTC, 2023) and applied the VAST package to estimate standardized CPUE. The settings of VAST were as follows: the number of knots was set to 200, covariates included Year and HBF, random effects include spatial effects, spatiotemporal effects, and vessel effects, and the time step was set to either year or quarter (**Table 1**). Within VAST, standardized CPUE was estimated using a delta-generalized linear mixed model (delta-GLMM) approach, which accounts for zero-inflated data by modeling both encounter probability and positive catch rate (Thorson, 2019).

Furthermore, to investigate the factors contributing to the decline in the CPUE index in 2020, we checked the center of biomass plot and estimated quarterly standardized CPUE for Area 2 and Area 2 with the northern areas (latitude 30–40°N, longitude 140–160°E) and compared it with the CPUE estimated using only Area 2 (**Figure 2**).

LF standardization

Size data were used for size standardization and the calculation of survey length composition. The specifications of the size data are the same as in the previous document and are therefore omitted here (Matsubara et al., 2024). First, we extracted data for fish caught between 1994 and 2022 within Area 2 and quarter 1 of the ISC area. Next, following the IATTC approach, we categorized albacore size into 5 cm bins within the range of 75–120 cm and aggregated the size data by year and latitude-longitude (5-degree resolution) for calculating length frequency (LF) (IATTC, 2023). To prevent model computation crashes, the number of knots was set to 25 and the setting of ANISO was FALSE, which mean ignoring anisotropy in spatial autocorrelations.

Survey length composition

Survey length composition is calculated using the following equation (IATTC, 2023).

$$LF(S)_{t,l} = \frac{\sum_s (a_s \times d_{s,t} \times lf_{s,t,l})}{\sum_l \sum_s (a_s \times d_{s,t} \times lf_{s,t,l})}$$

$LF(S)_{t,l}$ represents the survey length composition (LF for the survey fleet) in time t and grid s. Additionally, as denotes the area of grid s, $d_{s,t}$ represents the fish density in grid s and time t, and $lf_{s,t,l}$ indicates the LF in grid s, time t, and length l. Following the above equation, survey length composition was calculated using the standardized CPUE and standardized size estimates.

Results and Discussion

Standardized CPUE by VAST model and the factors for the decline of Index in 2020

The model for standard CPUE converged without any issues. The calculated standardized CPUE is shown in **Figure 3**. Between 1994 and 2000, CPUE showed a high trend, but in recent years, there has been a long-term declining trend. As with the previously submitted CPUE, a sharp decline was observed in 2020 (Matsubayashi et al., 2023; Nishimoto et al., 2024). The differences between the CPUE calculated using a different model are explained in a separate document (Ijima et al., 2025).

The sharp decline around 2020 is likely due to the movement of the albacore to the north. The center of biomass plot is shown in **Figure 4**, and a comparison of CPUE including Area2 and northward is shown in **Figure 5**. The center of biomass plot indicates that the center of the resource moved from south to north in 2020 (Fig 5, right). In particular, the right panel of Fig 5 shows that 2020 had the highest value on record, indicating that the albacore tuna in area 2 was located further north compared to other years. Additionally, when comparing CPUE by quarter, the standardized CPUE that included Area2 and its northern area was relatively higher in the first quarter of 2020 than the standardized CPUE that included only Area2. Based on the analysis above, the decline in CPUE in 2020 is likely attributed to the movement of the albacore resource to the north.

Survey length composition

Converged results were also obtained for the standardized LF. Following the IATTC approach (IATTC, 2023), the survey length composition from 1994 to 2022 was calculated, adjusted to match the year of size data measurement (**Figure 6**).

Future work

Based on these results, it is suggested that the following tasks be carried out in the future.

- Standardization of CPUE and size data across the entire ISC area: The run crashed when standardizing CPUE using logbook data from the entire ISC area. This issue is likely caused by calculations involving logbook data that span across 180°E. In the future, creating CPUE using data from the entire ISC area will allow continuous monitoring of adult albacore trends, even if adult fish appear outside Area 2.
- Implementation of the IATTC approach using sdmTMB: In the case of the VAST model, it has been reported that calculation results may change depending on updates to the embedded package (Punt, 2023). To avoid the loss of reproducibility due to package updates, conducting runs using sdmTMB of R package are considering. By applying sdmTMB, the runtime per model run is expected to be shorter. To ensure model convergence and reduce runtime, the data had been aggregated by 1×1 degree, year, and quarter. It is also expected that standardized CPUE can be analyzed directly from the original operational data with the application of sdmTMB.

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Table 1 VAST model settings for standardizing CPUE. Quarterly CPUE were calculated for considering the decline trend of index around 2020.

Area	Time step	knots	Covariate	Random effect
Area2	Yearly	200	Year, HBF	Vessel Spatial and Spatiotemporal
	Quartely			
Area2 + North area	Quartely			

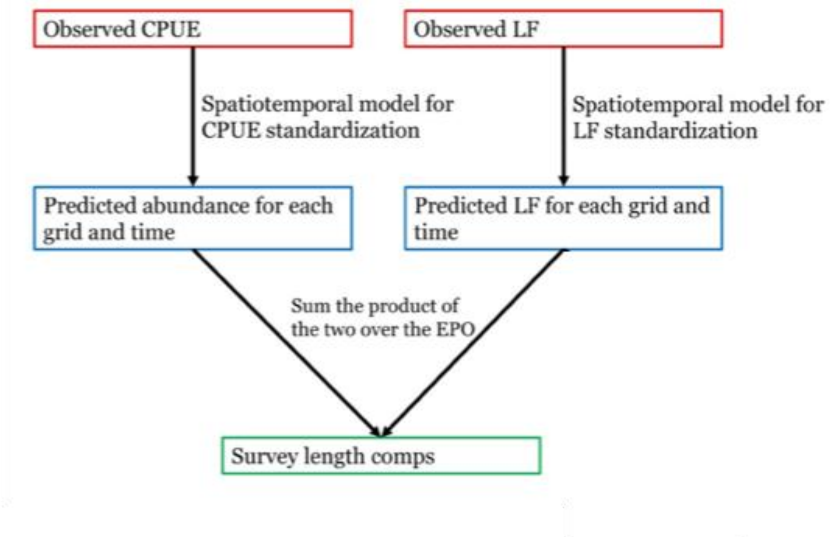

Figure 1 Summary of the IATTC's approaches to computing length compositions for longline fishery and survey fleets. Red, blue, and green boxes represent observed data, VAST predictions, and stock assessment inputs, respectively. (modified from IATTC, 2023)

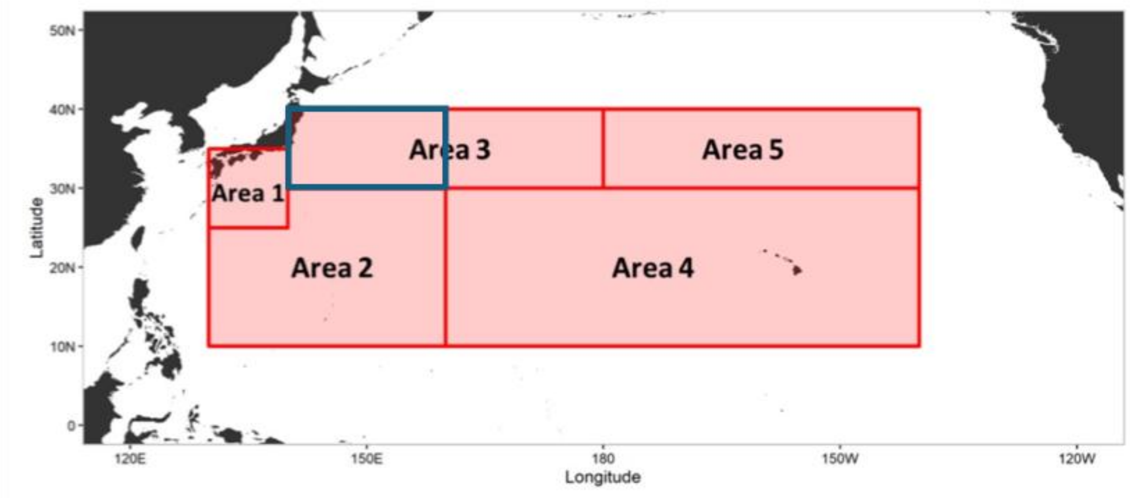

Figure 2 Area definition for Japanese longline CPUE analysis (modified from Nishimoto et al, 2024). Blue square means the additional analysis area for comparing the results of standardized CPUE between in Area 2 and Area2 + northern area (latitude 30–40°N, longitude 140–160°E), to identify the reason for the sharp decline in the index around 2020.

Figure 3 Standardized CPUE for Japanese longline in Area 2 at quarter 1 from 1994-2023 by VAST model. Grey shade means confidence interval between 5-95%. The x-axis indicates year and y-axis mean the relative standardized CPUE.

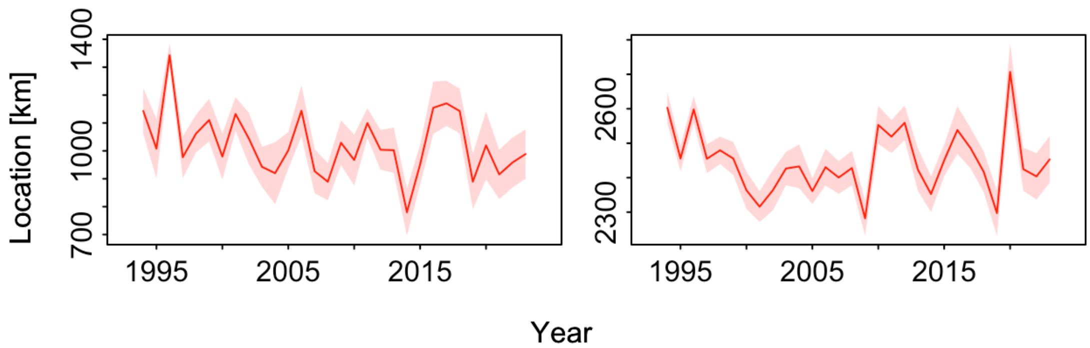

Figure 4 Center of biomass plot for standardized CPUE for Japanese longline in Area 2 at quarter 1 from 1994-2023 by VAST model. The left panel represents the east-west center, while the right panel represents the north-south center. Notably, around 2020, there was a sharp northward shift in the center (right panel), reaching its highest value since 1995 (a larger value indicates a more northern position). This suggests that the decline in the 2020 index may be attributed to albacore in Area 2 moving northward.

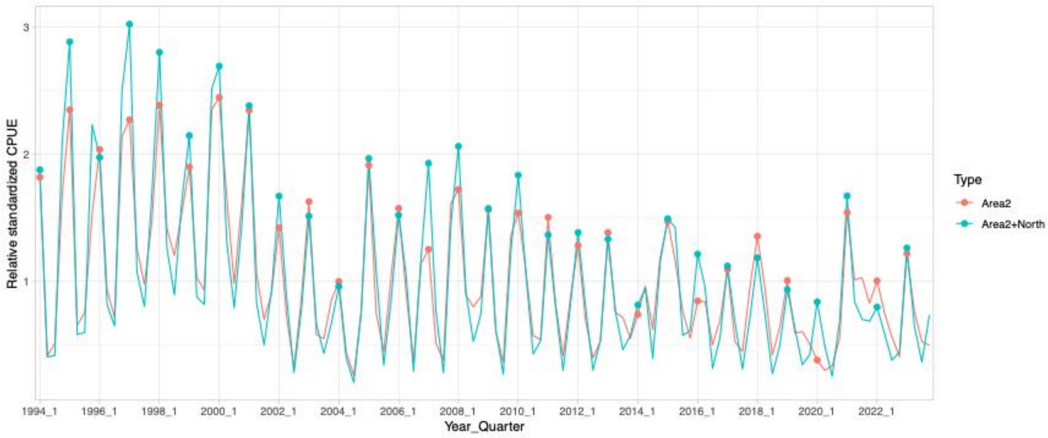

Figure 5 Comparison of standardized quarterly CPUE between Area2 and Area2 + northern area. The red line represents the relative value of standardized CPUE for Area2, while the blue line represents that for Area2 + northern area. Each point indicates the standardized CPUE for Quarter 1.

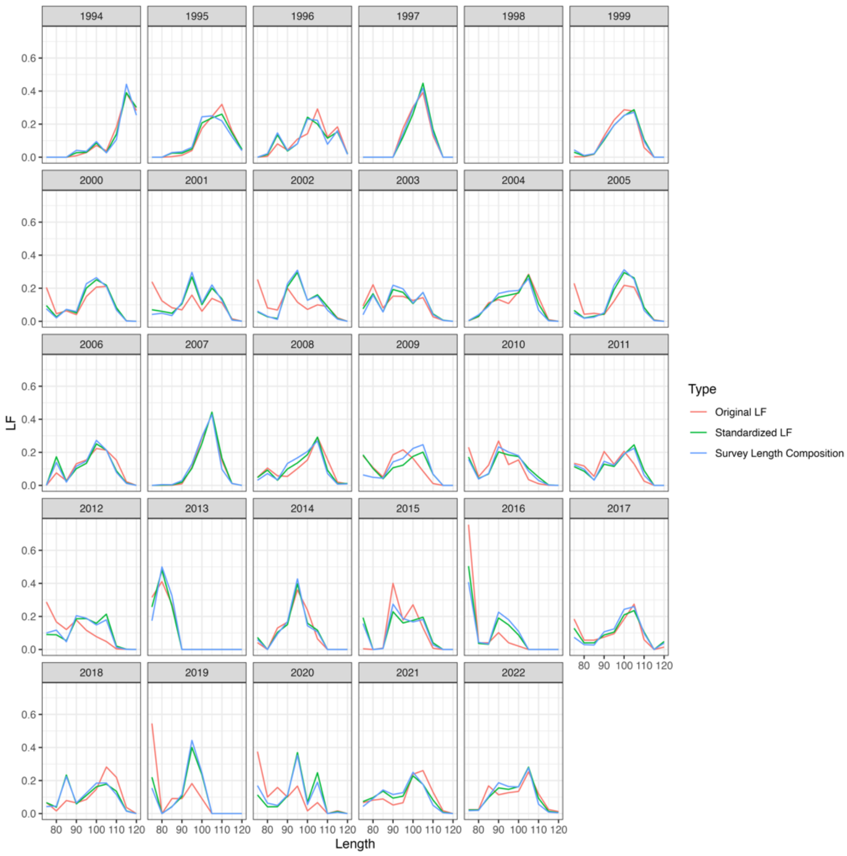

Figure 6 Survey length composition, which can be calculated by weighting the standardized size by the standardized CPUE for each grid and time (IATTC 2023). Red line showed the original length frequency aggregated by original size data, while green line showed the results of standardized LF, and blue line showed the results of survey length composition. Since the size data has been updated only up to 2022, the survey length composition was calculated for the period 1994–2022.