Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)
Standardization of CPUE for Splendid Alfonsino (Choshi District, Chiba Prefecture)

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Summary

Data	Catch and number of landings (day･vessel) data by month for vertical longline fishery of Splendid Alfonsino in Choshi District, Chiba Prefecture. Fishing operation location data are not included. Water temperature, direction, and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard’s Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day･vessel)
Data availability period	2003-2023
Period used for standardization	2003-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical value as fixed effects) Water temperature, current speed, the latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, the water temperature at the 200 m depth layer, the latitudinal difference in the northern edge of the Kuroshio between longitudes 138°E and 139°E
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects
Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.

Results of CPUE standardization	Standardized CPUE decreased after 2008, began to increase after 2014, and reached its highest value during the analysis period in 2023. Although the long-term trend of nominal CPUE was similar to standardized CPUE, nominal CPUE values were significantly higher from 2006 to 2010, and the standardized CPUE values were significantly higher from 2018 onwards.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We used “year”, “season”, ”area”, and “the distance to the Kuroshio axis” (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised by fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds and entire habitat of the stock) (Watari et al., 2023).

As a result, it was determined that the standardized CPUE for the Choshi district of Chiba Prefecture is better at taking into account the effects of environmental factors. Since the model diagnostic results were good, it was decided to introduce the CPUE as one of the tuning indices for the VPA of the Splendid Alfonsino of Pacific Japan.

This fiscal year, as in previous fiscal years, the standardization model for the Choshi district of Chiba Prefecture has been updated with the most recent data for the current fiscal year.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Choshi district of Chiba Prefecture, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day・vessel) and does not include fishing operation location data. The standardization period was 2003-2023, and all records were used for the analysis.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Choshi district, the latitude of the Kuroshio northern edge at 141°E (Lat_141) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) was calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were used as indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. For the Choshi district, grids 26-29 in Fig. 1 were selected as fishing grounds for analysis. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Directfct) after monthly averaging. For current direction and current speed, the respective daily data were first converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.

Continuous variables were treated as first-order effects because no non-linearity was detected when the relationship between environmental variables and nominal CPUE were plotted (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.

Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_400 +
  Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_400 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_400 + Direcfct_Bottom +
Lat_141 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Only monthly CPUE data are currently available. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.. The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike’s Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and than select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The

best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plot, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Quarter + Temperature_200 + Lat138_139

For the Choshi district, as a result of the model selection process using an exhaustive search based on AIC, 26 models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. In the best model of the previous fiscal year, no explanatory variables associated with the influence of the Kuroshio were selected. However, for this fiscal year, the latitudinal differences in the Kuroshio northern edge between 138°E-139°E were included, and for many of the other models within the range of minimum AIC+2, variables of the latitude of the Kuroshio’s northern edge at 141°E and the Kuroshio intrusion were selected. Additionally, CPUE in the best model tended to increase as the water temperature in the fishing grounds decreased (Fig. 4).

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. The standardized CPUE continued to decrease from 2008 to 2013 but began to increase after 2014, reaching its highest value during the analysis period in 2023. Although the long-term trend of nominal CPUE was similar to standardized CPUE, nominal CPUE values were significantly higher from 2006 to 2010, and the standardized CPUE values were significantly higher from 2018 onwards.

3.2 Comparison with the Previous Fiscal Year’s Results

In the previous fiscal year, seasonal effects were not included in the models selected based on the conditions outlined in 2.4 Model Selection. However, since said area could also be affected by seasonal variations in the Oyashio current, the best model was the one that included seasonal effects, with emphasis on explanatory power in terms of environment. This fiscal year, seasonal effects were selected based on the basic model selection conditions without considering additional information, resulting in the same explanatory variables being included in the best model as in the previous fiscal year. However, this fiscal year, the variable representing the latitudinal difference in the northern edge of the Kuroshio between 138°E and 139°E was selected. While the variable was not included in the best model previous fiscal year, it was present in many model candidates. Since there was no significant difference in the annual trend of standardized CPUE obtained this fiscal year from the previous fiscal year, it can be concluded that the addition of one year of data did not result in a significant change in the model’s estimated results.

Cited literature

Kuroda, H., Setou, T., Kakehi, S., Ito, S., Taneda, T., Azumaya, T., Inagake, D., Hiroe, Y., Morinaga, K., Okazaki, M., Yokota, T., Okunishi, T., Aoki, K., Shimizu, Y., Hasegawa, D., and Watanabe, T. (2017) Recent advances in Japanese fisheries science in the Kuroshio-Oyashio region through development of the FRA-ROMS ocean forecast system: Overview of the reproducibility of reanalysis products. Open Journal of Marine Science, 7, 62–90.

Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

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Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction					Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Sea-son	Year	df	logLik	AIC	delta
	0	100	200	400	Bottom	141°E	138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom						
2.22		+				0.06	0.04						-0.19		0.01					+	+	36	67.0	-62.0	0.0
2.03		+				0.06	0.04					-0.13			0.01					+	+	36	66.9	-61.8	0.3
4.74							0.04			0.10							-0.03			+	+	28	58.7	-61.5	0.6
2.60	+					0.04	0.04						-0.18		0.02					+	+	36	66.7	-61.4	0.6
4.12	+						0.04						-0.15		0.02					+	+	35	65.6	-61.2	0.8
2.38	+					0.05	0.04					-0.12			0.02					+	+	36	66.6	-61.2	0.9
4.76				+			0.04			0.18							-0.04			+	+	35	65.5	-61.1	1.0
2.14		+				0.07	0.04						-0.18							+	+	35	65.5	-60.9	1.1
4.65							0.04										-0.02			+	+	27	57.4	-60.8	1.2
4.13	+						0.03		-0.03				-0.17		0.02					+	+	36	66.4	-60.8	1.3
4.15		+					0.04						-0.16		0.02					+	+	35	65.3	-60.7	1.4
1.98		+				0.06	0.04	0.02					-0.20		0.01					+	+	37	67.3	-60.5	1.5
4.12	+						0.04					-0.09			0.02					+	+	35	65.3	-60.5	1.5
2.16		+				0.06	0.04						-0.36					0.03		+	+	36	66.2	-60.5	1.6
4.24							0.04					-0.11			0.01					+	+	28	58.2	-60.4	1.6
2.02		+				0.06	0.04				-0.1				0.01					+	+	36	66.2	-60.4	1.6
1.99		+				0.07	0.04					-0.11								+	+	35	65.2	-60.3	1.7
4.13	+								-0.04				-0.18		0.02					+	+	35	65.1	-60.3	1.8
4.67							0.04									-0.01				+	+	27	57.1	-60.2	1.8
4.13	+						0.04								0.02					+	+	34	64.1	-60.2	1.9
2.40		+				0.05	0.04		-0.01				-0.19		0.01					+	+	37	67.1	-60.1	1.9
4.13	+								-0.04			-0.12			0.02					+	+	35	65.1	-60.1	1.9
4.78							0.04			0.08						-0.02				+	+	28	58.1	-60.1	1.9
4.76							0.04		-0.02	0.10							-0.03			+	+	29	59.1	-60.1	1.9
1.84		+				0.07	0.04	0.01				-0.13			0.01					+	+	37	67.0	-60.1	2.0
4.13	+						0.03		-0.03			-0.11			0.02					+	+	36	66.0	-60.1	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2003	1.02	1.02	0.90	1.15	0.06
2004	1.06	1.06	0.88	1.24	0.08
2005	0.99	0.96	0.83	1.11	0.07
2006	1.12	1.06	0.94	1.22	0.06
2007	1.20	1.17	1.07	1.25	0.04
2008	1.05	0.98	0.81	1.14	0.09
2009	1.06	0.97	0.80	1.15	0.09
2010	0.99	0.94	0.81	1.09	0.08
2011	0.77	0.77	0.69	0.85	0.05
2012	0.74	0.73	0.63	0.84	0.08
2013	0.59	0.59	0.54	0.64	0.04
2014	0.66	0.65	0.58	0.72	0.05
2015	0.71	0.69	0.61	0.77	0.06
2016	0.88	0.87	0.80	0.95	0.04
2017	0.98	0.98	0.92	1.05	0.04
2018	1.08	1.13	1.03	1.22	0.04
2019	1.14	1.23	1.12	1.34	0.05
2020	1.20	1.23	1.13	1.35	0.05
2021	1.14	1.23	1.09	1.37	0.06
2022	1.23	1.28	1.19	1.36	0.04
2023	1.38	1.47	1.34	1.61	0.05

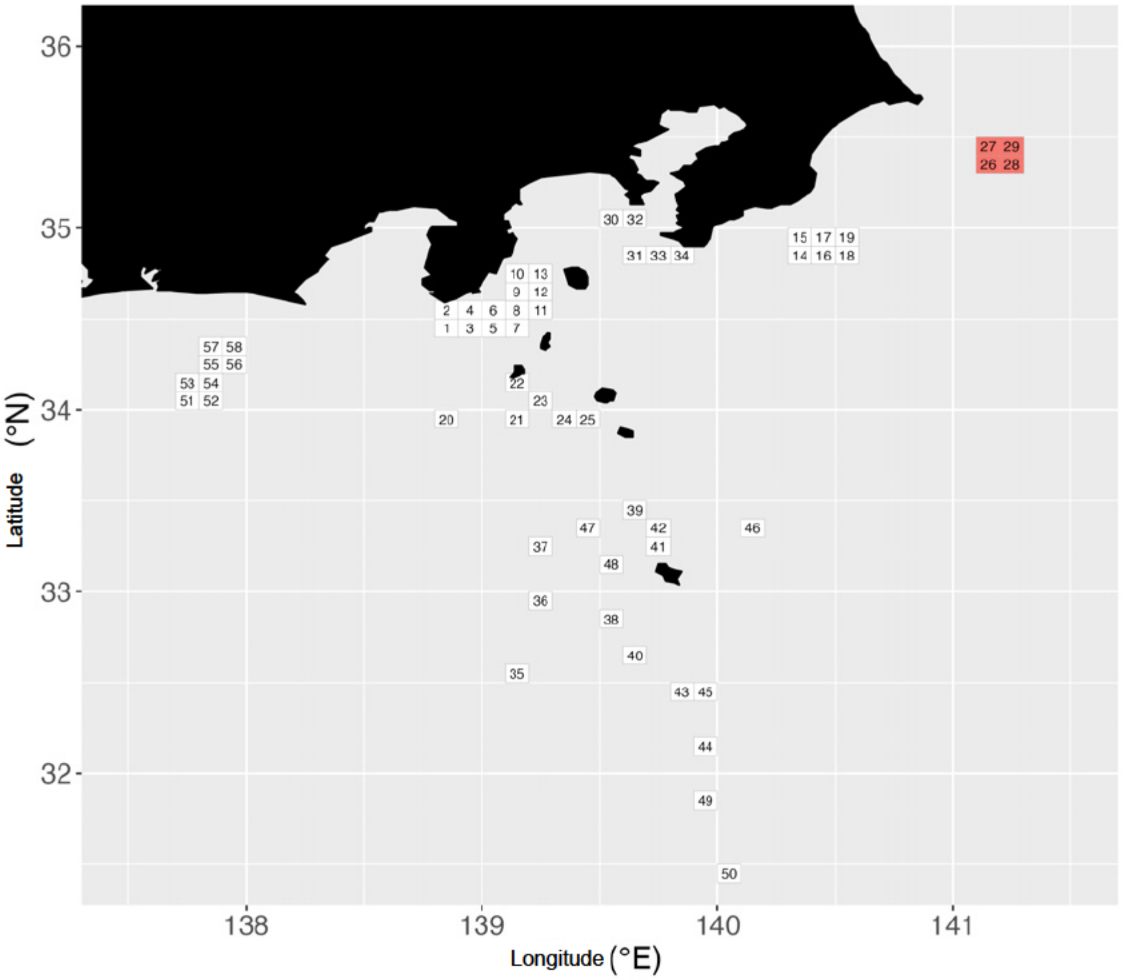

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values -
Data extracted for 0.1° grid units of latitude and longitude
For the Choshi district, grids 26-29 were used.

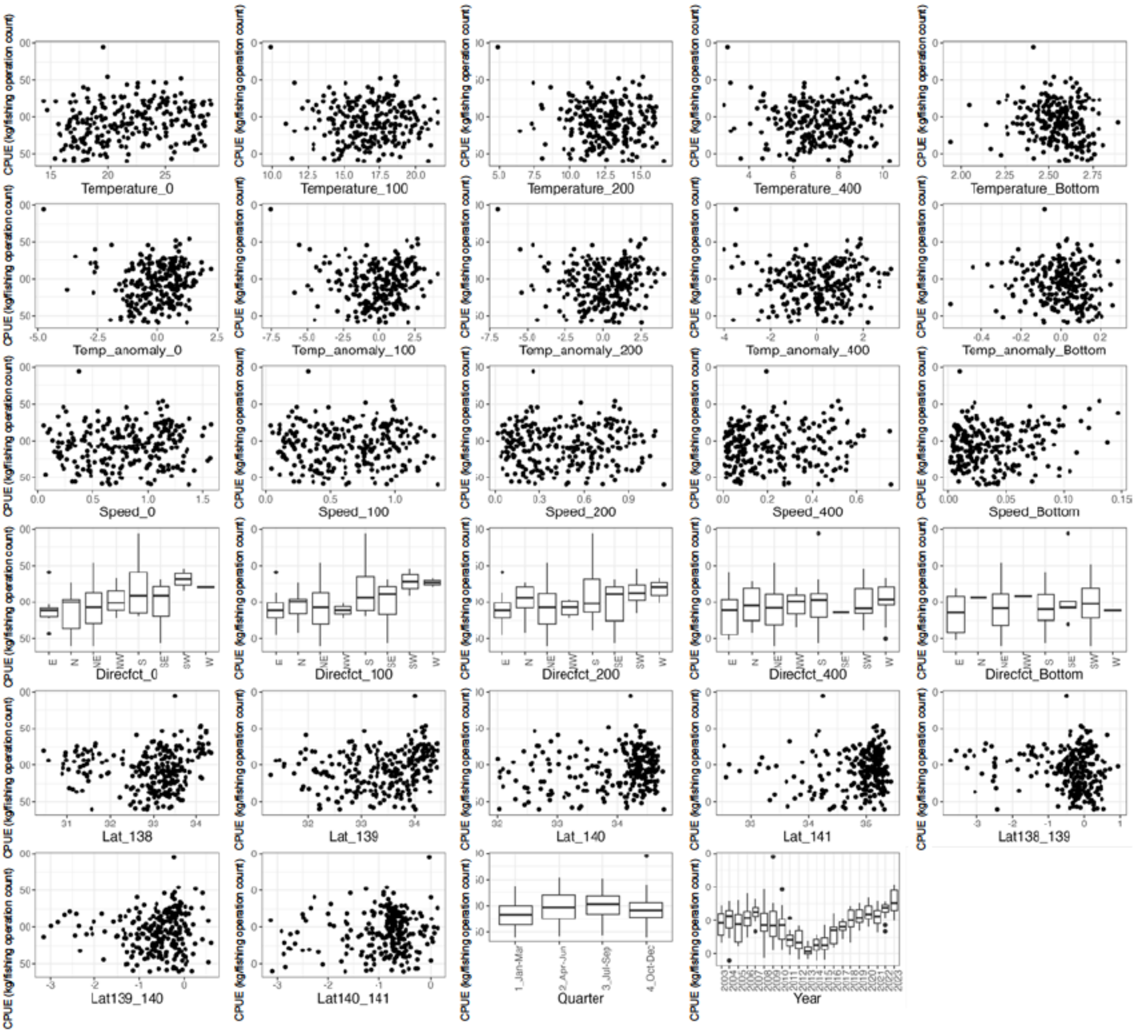

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

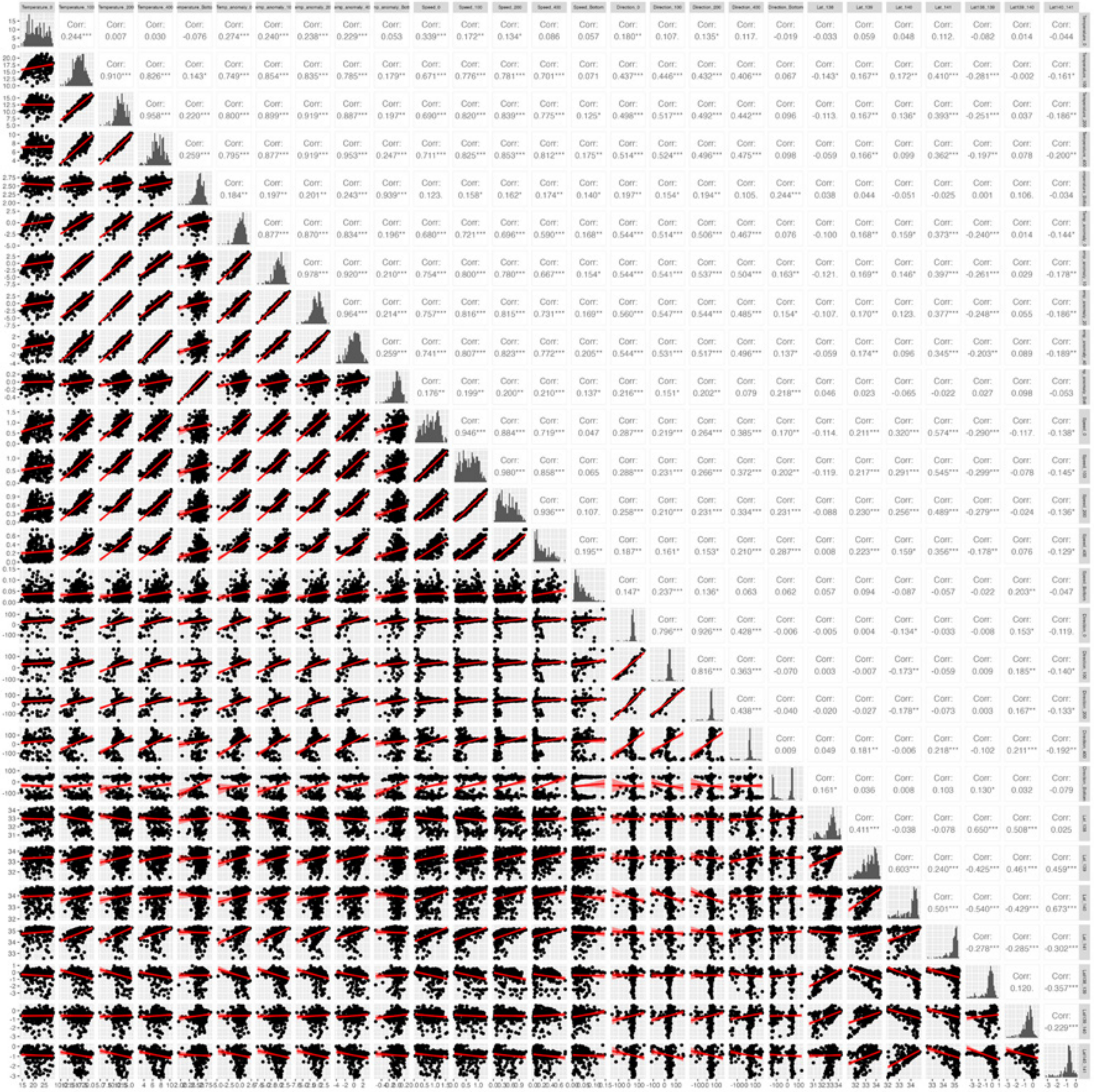

Fig. 3. Correlation between the marine environmental data used in the standardization model

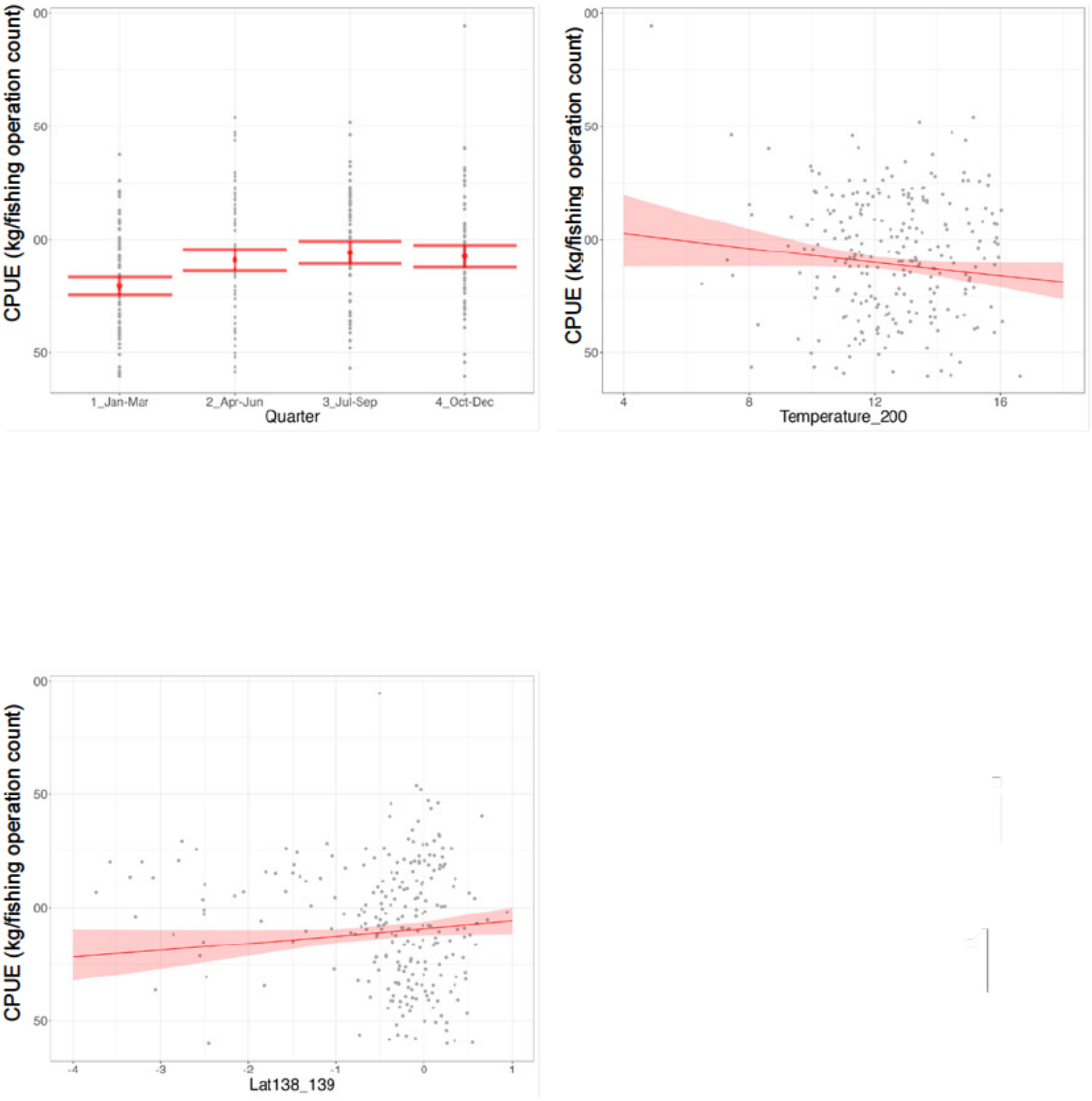

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

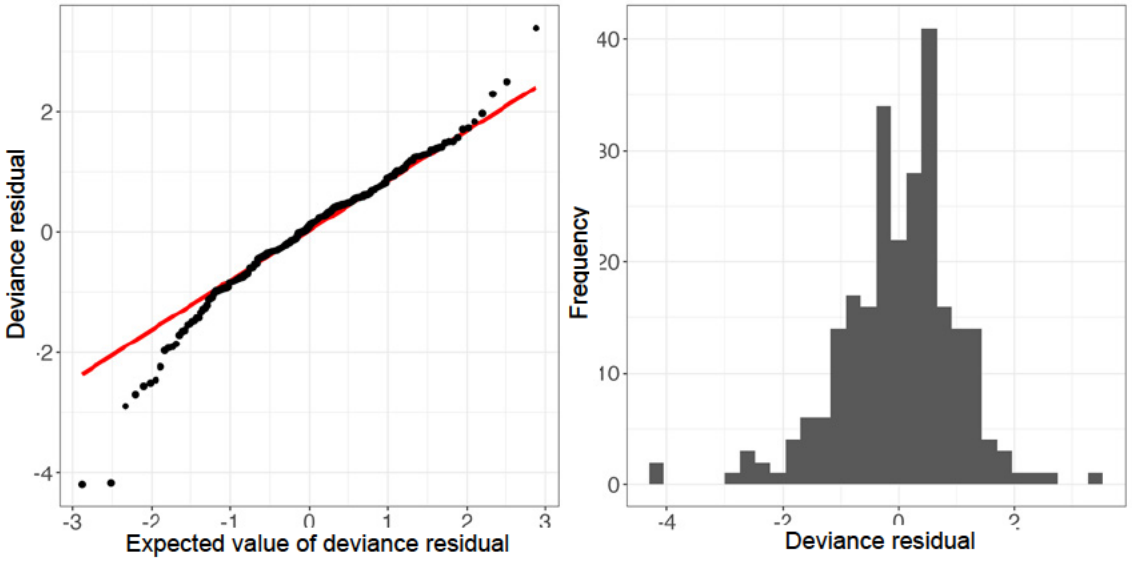

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

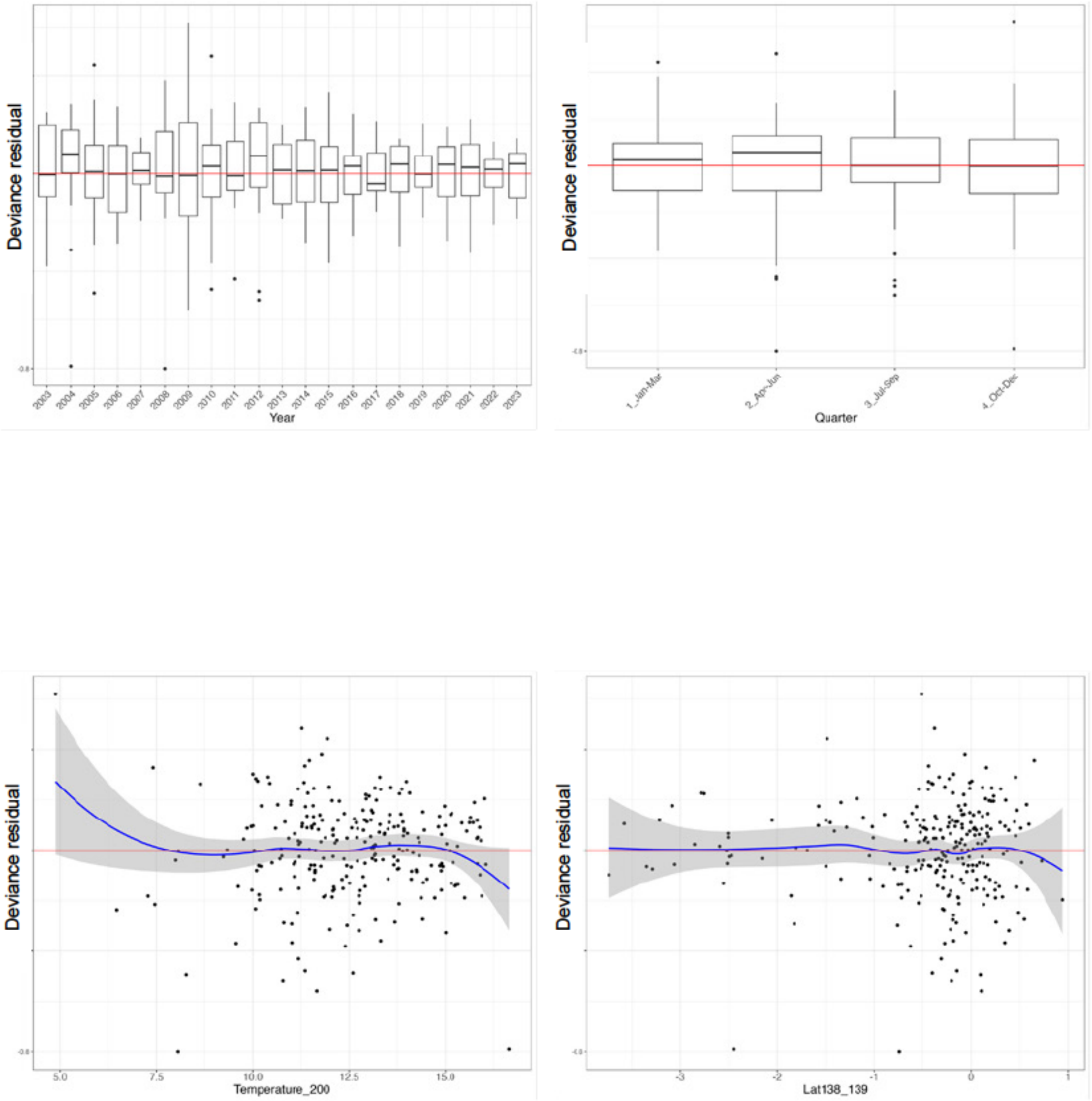

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Temperature_200 and Lat138_139 represent fitted smoothing curves (loess) and their 95% confidence intervals.

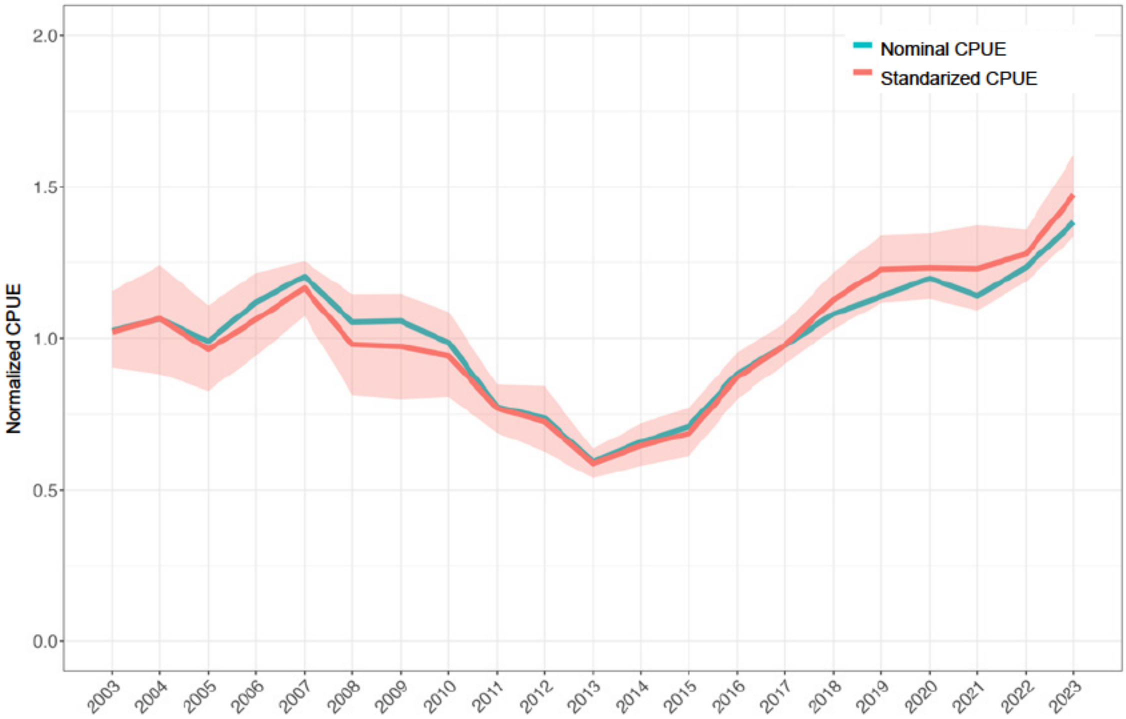

Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Lat138_139 + Quarter + Temperature_200 + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	4.647	0.132	35.141	0.0000	***
Lat138_139	0.037	0.020	1.813	0.0711	.
Quarter2_Apr-Jun	0.135	0.037	3.636	0.0003	***
Quarter3_Jul-Sep	0.170	0.038	4.510	0.0000	***
Quarter4_Oct-Dec	0.153	0.036	4.197	0.0000	***
Temperature_200	-0.017	0.009	-1.858	0.0644	.
Year2004	0.042	0.085	0.492	0.6230	
Year2005	-0.059	0.084	-0.694	0.4886	
Year2006	0.039	0.086	0.454	0.6499	
Year2007	0.133	0.085	1.566	0.1188	
Year2008	-0.041	0.085	-0.488	0.6261	
Year2009	-0.049	0.085	-0.575	0.5658	
Year2010	-0.081	0.084	-0.966	0.3350	
Year2011	-0.281	0.083	-3.379	0.0009	***
Year2012	-0.341	0.083	-4.093	0.0001	***
Year2013	-0.552	0.083	-6.622	0.0000	***
Year2014	-0.457	0.083	-5.491	0.0000	***
Year2015	-0.394	0.084	-4.718	0.0000	***
Year2016	-0.158	0.083	-1.897	0.0592	.
Year2017	-0.043	0.083	-0.520	0.6036	
Year2018	0.099	0.085	1.165	0.2451	
Year2019	0.185	0.089	2.081	0.0386	*
Year2020	0.189	0.084	2.245	0.0258	*
Year2021	0.186	0.087	2.141	0.0333	*
Year2022	0.225	0.084	2.682	0.0079	**

	Estimate	Standard Error	z value	Pr(>|z|)	
Year2023	0.367	0.086	4.282	0.0000	***

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 0.04138918)

Null deviance: 23.4 on 251 degrees of freedom

Residual deviance: 9.354 on 226 degrees of freedom

AIC: -60.85

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

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Summary

Data	Catch and number of landings (day･vessel) data by month for vertical longline fishery of Splendid Alfonsino in Katsuura District, Chiba Prefecture. Fishing operation location data are not included. Water temperature, direction and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard’s Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day･vessel)
Data availability period	2000-2023
Period used for standardization	2000-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical value as fixed effects)Water temperature, current speed, the latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, water temperature at the 0 m layer, current speed at 0 m layer, current direction at 100 m layer, latitudinal difference in the northern edge of the Kuroshio between longitudes 140°E and 141°E
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects
Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.

Results of CPUE standardization	Standardized CPUE exhibited a long-term declining trend from 2007 to 2013, followed by a period of stability until 2017. However, an increasing trend emerged from 2018 until recently, with the highest value during the analysis period being recorded in 2023. While nominal CPUE exhibited similar trends, the standardized CPUE values were higher during 2002-2005, 2010, and 2017 onwards, while nominal CPUE values were higher in other years.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We used “year”, “season”, ”area”, and “the distance to the Kuroshio axis” (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised by fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds and entire habitat of the stock) (Watari et al., 2023). As the results of the estimation using data from the Katsuura district of Chiba Prefecture showed generally acceptable model diagnostic results, demonstrating correction of the lower CPUE due to the effects of the Kuroshio path and current speed in the fishing grounds, it was decided to use the yearly trend derived from this model as one of the tuning indices for the VPA of the Splendid Alfonsino of Pacific Japan.

This fiscal year, as in previous fiscal years, the standardization model for the Katsuura district of Chiba Prefecture has been updated with the most recent data for the current fiscal year.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Katsuura district of Chiba Prefecture, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day･vessel) and does not include fishing operation location data. The standardization period was 2000-2023, and all records were used for the analysis.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Katsuura district, the latitude of the Kuroshio northern edge at 140°E (Lat_140) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. In addition, the latitudinal difference at the Kuroshio northern edge between longitudes (namely, the Kuroshio slope, for the three intervals 138°E-139°E, 139°E-140°E, and 140°E-141°E. Lat138_139, Lat139_140, and Lat140_141, respectively) was used as an indicator of “Kuroshio intrusion” to examine how the Kuroshio current flow patterns, as represented by large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. For the Katsuura district, grids 14-19 in Fig. 1 were selected as fishing grounds for analysis. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Direcfct) after monthly averaging. For current direction and current speed, the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.

Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.

Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_400 +
Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_400 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_400 + Direcfct_Bottom +
Lat_140 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.. The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike's Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plot, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Quarter + Temperature_0 + Speed_0 + Direcfct_100 + Lat140_141

For the Katsuura district, as a result of the model selection process using an exhaustive search based on AIC, five models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. Other models within the minimum AIC+2 range suggested that, in addition to the explanatory variables selected in the best model, the position of the Kuroshio northern edge was also selected in many other models, demonstrating that explanatory variables associated with the effect of the Kuroshio and marine environment in the fishing ground tend to be selected as effective variable in many cases. The CPUE responses to each of the selected explanatory variables in the best model (Fig. 4) also suggested the effect of the Kuroshio intrusion, current strength fluctuations, and water temperature variations on the CPUE.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. Standardized CPUE exhibited a long-term declining trend from 2007 to 2013, followed by a period of stability until 2017. However, an increasing trend emerged from 2018 until recently, with the highest value during the analysis period being recorded in 2023. While nominal CPUE exhibited similar trends, the standardized CPUE values were higher during 2002-2005, 2010, and 2017 onwards, while nominal CPUE values were higher in other years.

3.2 Comparison with the Previous Fiscal Year’s Results

The explanatory variables selected for this fiscal year’s best model were the same as those of the previous fiscal year, and there were no significant differences from the previous year in the standardized CPUE trends derived from the best model.

Cited Literature

Kuroda, H., Setou, T., Kakehi, S., Ito, S., Taneda, T., Azumaya, T., Inagake, D., Hiroe, Y., Morinaga, K., Okazaki, M., Yokota, T., Okunishi, T., Aoki, K., Shimizu, Y., Hasegawa, D., and Watanabe, T. (2017) Recent advances in Japanese fisheries science in the Kuroshio-Oyashio region through development of the FRA-ROMS ocean forecast system: Overview of the reproducibility of reanalysis products. Open Journal of Marine Science, 7, 62–90.

Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

Watari, S., and Hanzawa, Y. (2022) FY 2021 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FY 2021 Fisheries Stock Assessment in the Waters around Japan, Japan Fisheries Research and Education Society, Fisheries Agency. FRA-SA2021-RC02-2. https://abchan.fra.go.jp/wpt/wp-content/uploads/2021/details_2021_37.pdf

Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction					Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Season	Year	df	logLik	AIC	delta
	0	100	200	400	Bottom	140°E	138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom						
2.14		+				0.06			-0.11	-0.23					-0.04					+	+	37	107.9	-141.7	0.0
4.12		+							-0.08	-0.18					-0.04					+	+	36	106.7	-141.4	0.3
1.83	+					0.07			-0.12	-0.23					-0.04					+	+	37	107.2	-140.3	1.4
2.16		+				0.06	0		-0.11	-0.23					-0.04					+	+	38	107.9	-139.8	1.9
2.17		+				0.06		0	-0.11	-0.23					-0.04					+	+	38	107.9	-139.7	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2000	1.09	1.01	0.89	1.13	0.06
2001	1.30	1.19	1.07	1.30	0.05
2002	1.02	1.06	1.01	1.11	0.03
2003	0.98	1.05	0.98	1.13	0.04
2004	0.97	1.04	0.95	1.13	0.04
2005	1.09	1.17	1.06	1.27	0.05
2006	1.21	1.20	0.99	1.38	0.09
2007	1.23	1.16	1.02	1.34	0.07
2008	1.16	1.06	0.96	1.19	0.05
2009	1.13	0.99	0.89	1.12	0.06
2010	1.00	1.02	0.91	1.13	0.06
2011	0.83	0.83	0.76	0.90	0.04
2012	0.95	0.92	0.80	1.06	0.07
2013	0.78	0.70	0.63	0.77	0.05
2014	0.79	0.74	0.68	0.80	0.04
2015	0.82	0.77	0.68	0.85	0.06
2016	0.83	0.78	0.68	0.91	0.07
2017	0.71	0.73	0.66	0.81	0.05
2018	0.81	0.90	0.80	1.01	0.06
2019	0.76	0.85	0.74	0.96	0.07
2020	1.03	1.09	1.00	1.19	0.04
2021	1.00	1.09	1.00	1.17	0.04
2022	1.24	1.31	1.17	1.47	0.06
2023	1.27	1.35	1.15	1.57	0.08

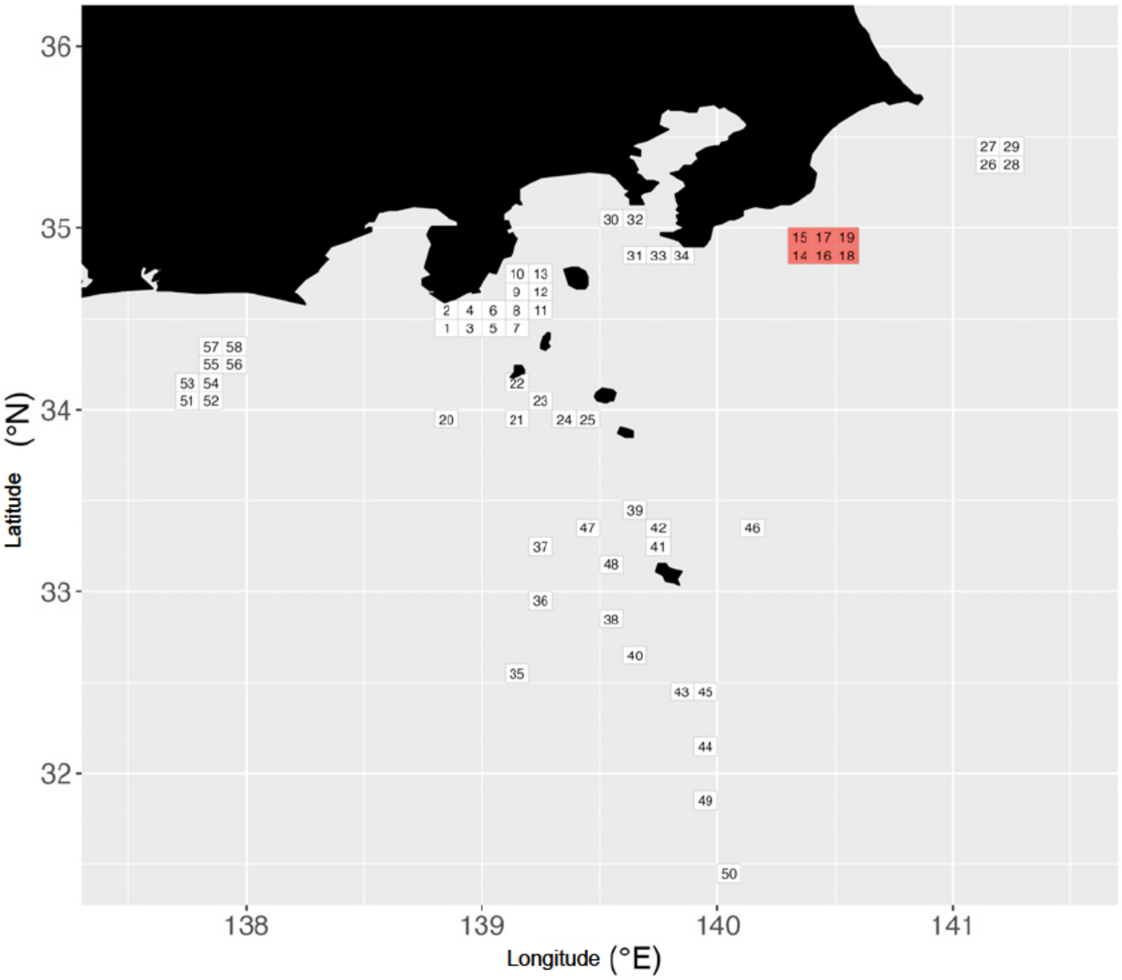

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values - Data extracted for 0.1° grid units of latitude and longitude

For the Katsuura district, grids 14-19 were used.

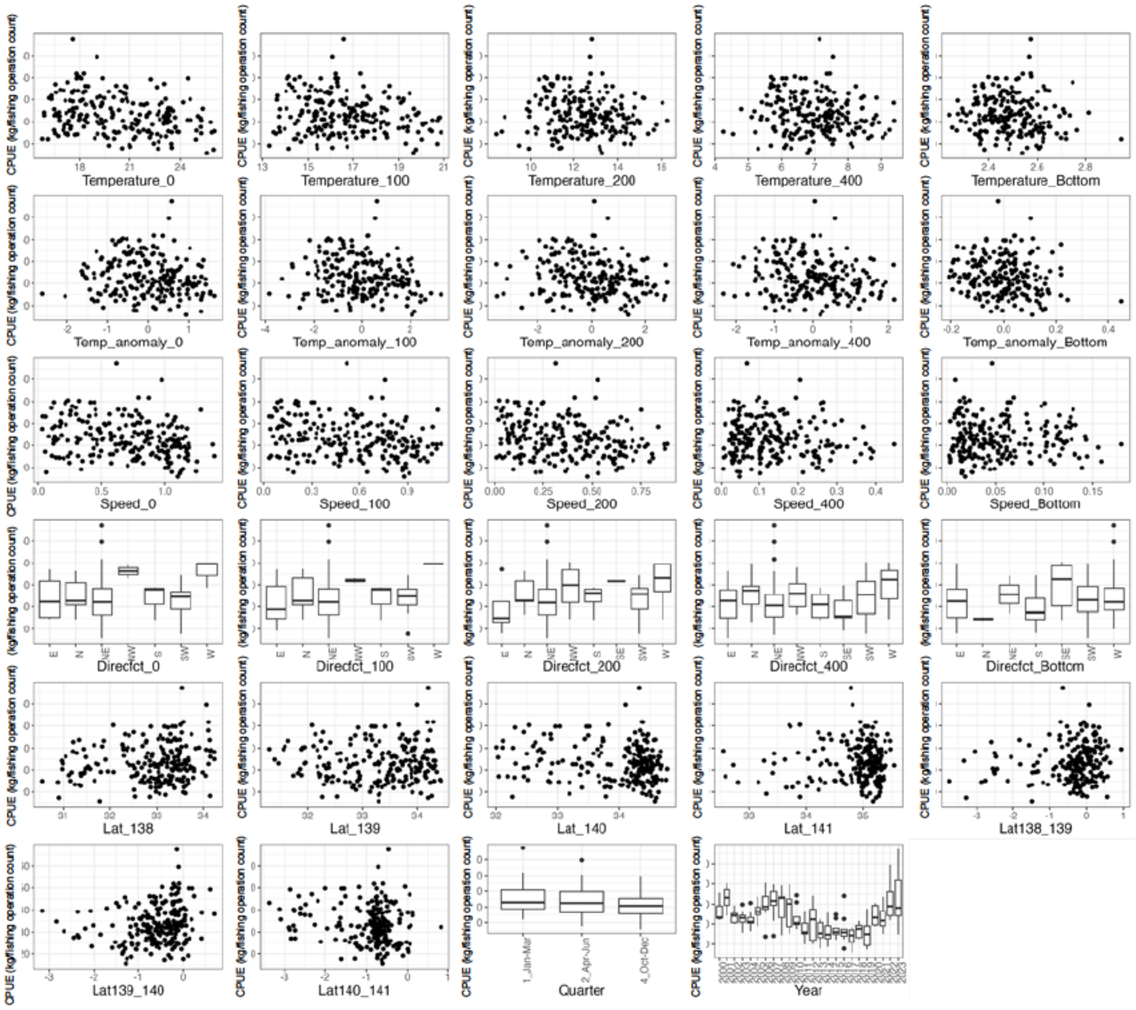

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

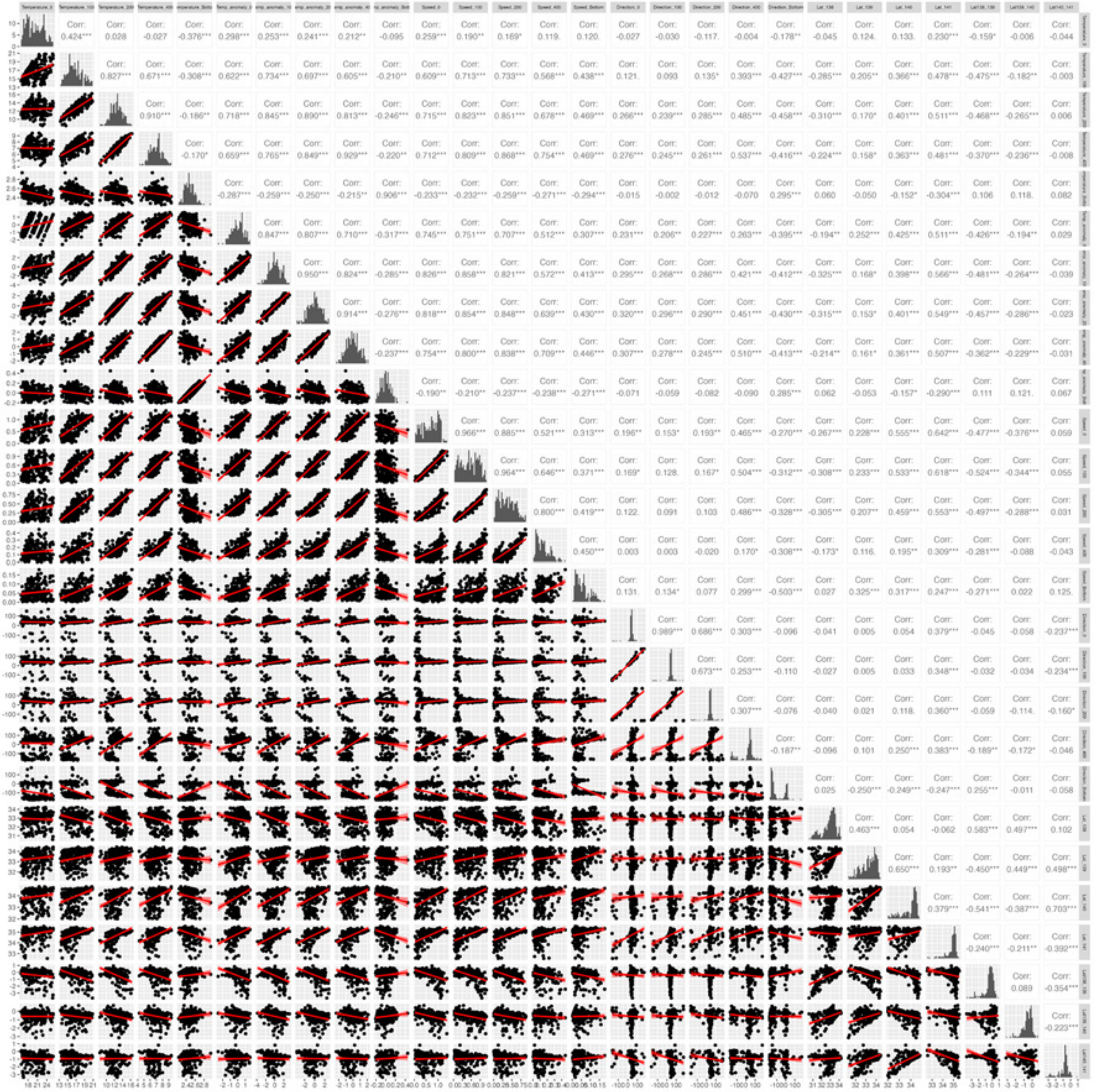

Fig. 3. Correlation between the marine environmental data used in the standardization model

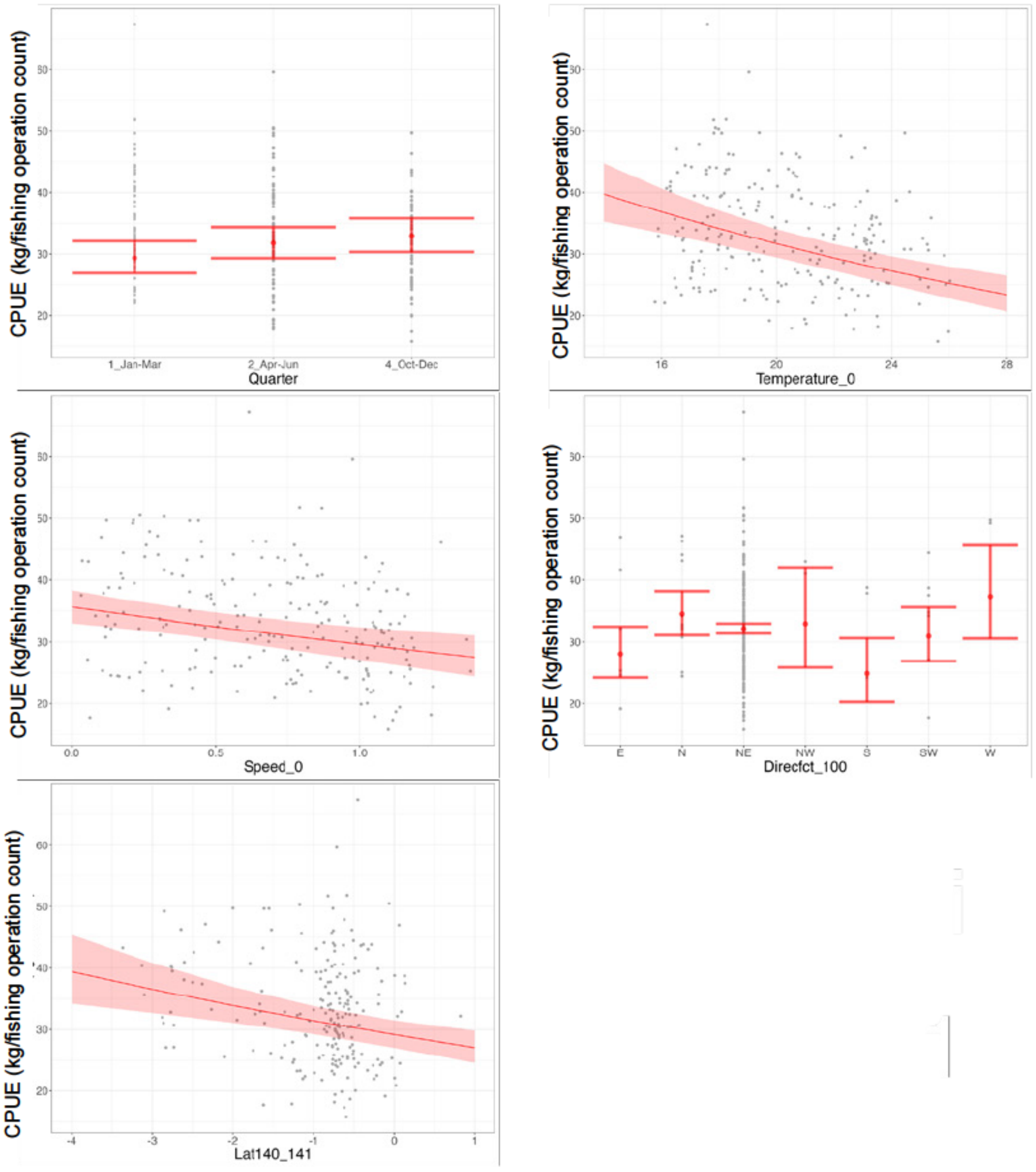

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

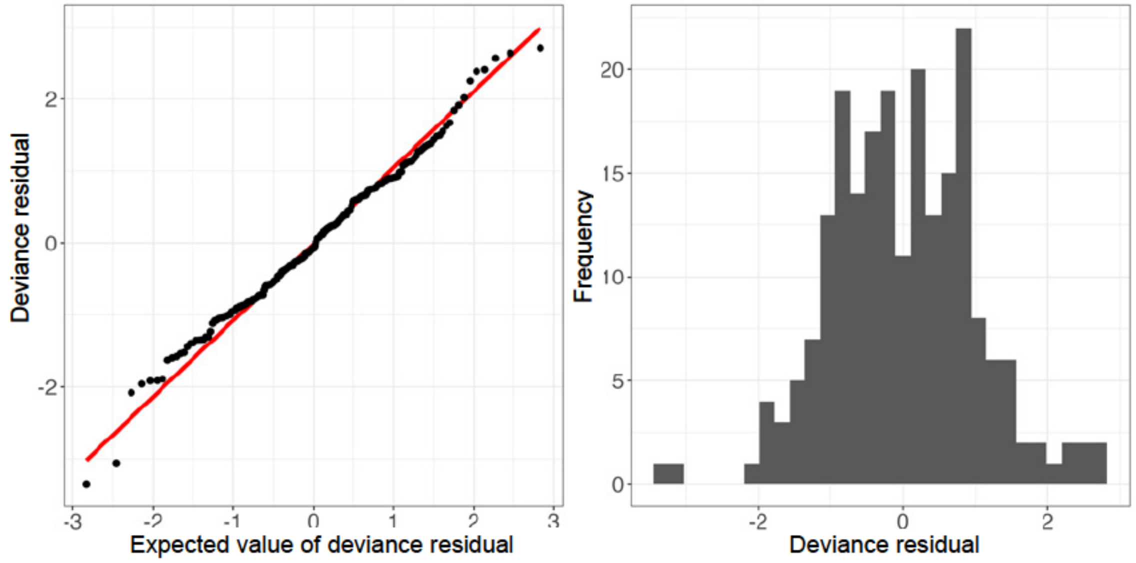

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

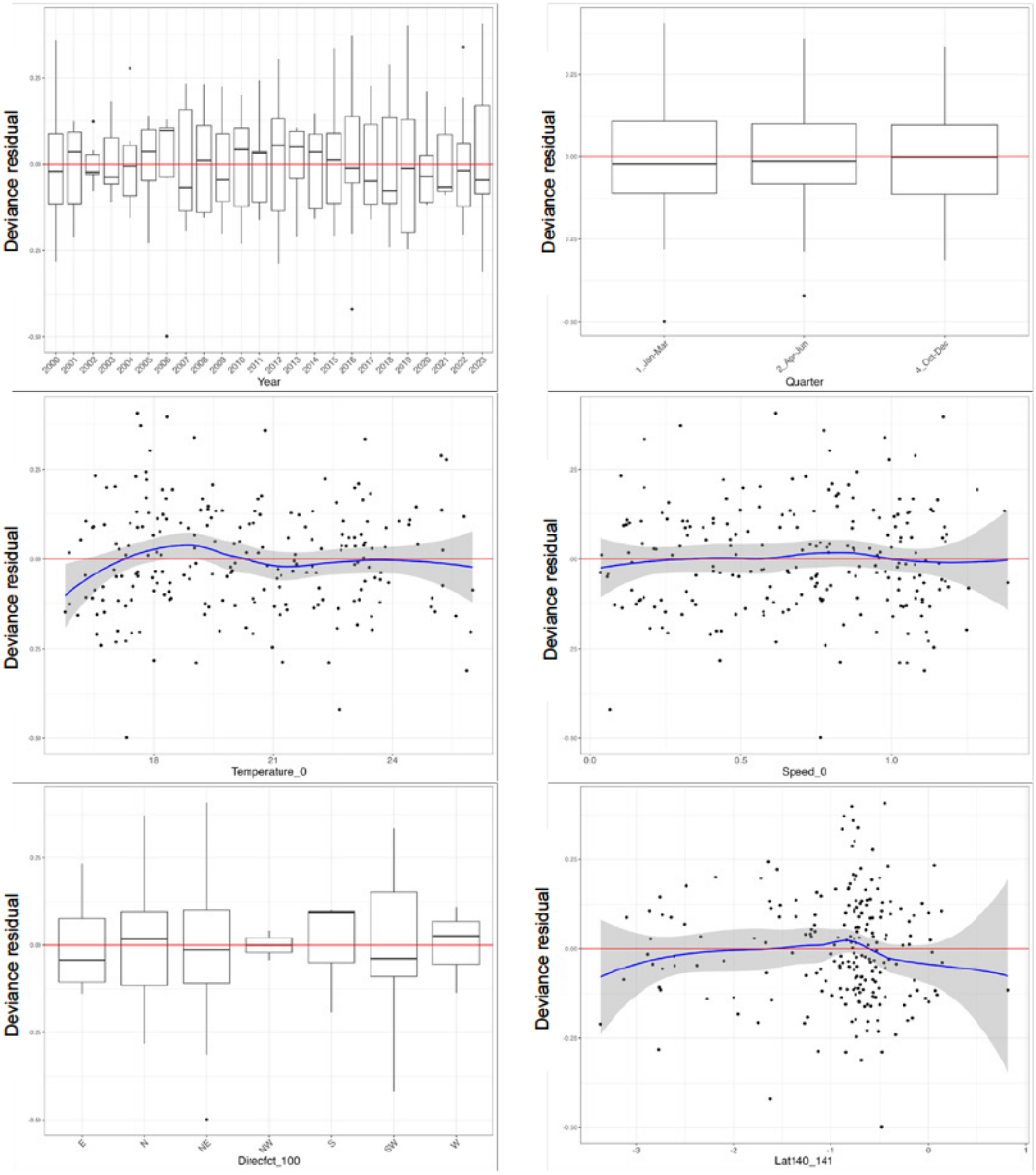

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Temperature_0, Speed_0, and Lat140_141 represent fitted smoothing curves (loess) and their 95% confidence intervals.

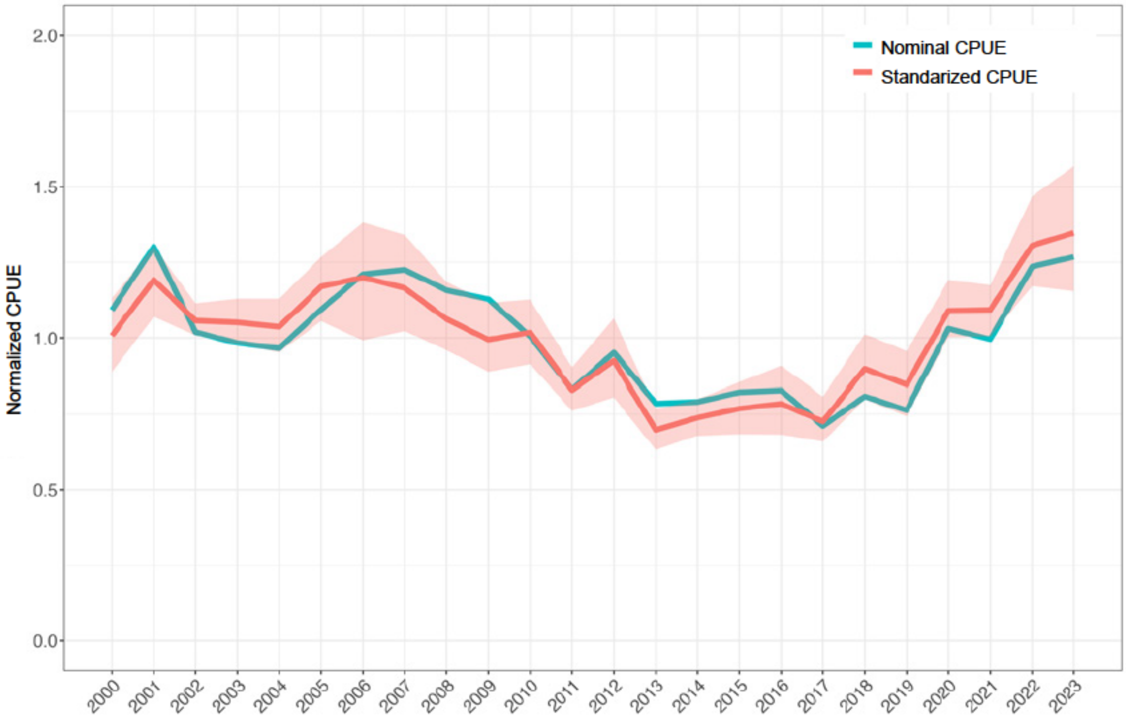

Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Direcfct_100 + Lat140_141 + Quarter + Speed_0 + Temperature_0 + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	4.121	0.150	27.401	0.0000	***
Direcfct_100N	0.205	0.089	2.313	0.0219	*
Direcfct_100NE	0.137	0.077	1.781	0.0765	.
Direcfct_100NW	0.161	0.143	1.122	0.2632	
Direcfct_100S	-0.121	0.121	-0.999	0.3193	
Direcfct_100SW	0.097	0.098	0.992	0.3225	
Direcfct_100W	0.285	0.120	2.376	0.0185	*
Lat140_141	-0.075	0.019	-3.966	0.0001	***
Quarter2_Apr-Jun	0.078	0.035	2.227	0.0272	*
Quarter4_Oct-Dec	0.115	0.045	2.554	0.0115	*
Speed_0	-0.183	0.050	-3.658	0.0003	***
Temperature_0	-0.038	0.007	-5.334	0.0000	***
Year2001	0.168	0.079	2.130	0.0345	*
Year2002	0.048	0.078	0.611	0.5421	
Year2003	0.042	0.079	0.539	0.5904	
Year2004	0.029	0.079	0.365	0.7152	
Year2005	0.149	0.079	1.894	0.0599	.
Year2006	0.175	0.082	2.121	0.0353	*
Year2007	0.145	0.081	1.799	0.0736	.
Year2008	0.053	0.078	0.679	0.4982	
Year2009	-0.013	0.077	-0.168	0.8666	
Year2010	0.010	0.079	0.131	0.8957	
Year2011	-0.196	0.078	-2.531	0.0122	*
Year2012	-0.086	0.077	-1.113	0.2673	
Year2013	-0.368	0.077	-4.802	0.0000	***

	Estimate	Standard Error	z value	Pr(>|z|)	
Year2014	-0.311	0.076	-4.081	0.0001	***
Year2015	-0.271	0.076	-3.545	0.0005	***
Year2016	-0.251	0.077	-3.270	0.0013	**
Year2017	-0.328	0.078	-4.184	0.0000	***
Year2018	-0.115	0.080	-1.431	0.1541	
Year2019	-0.175	0.081	-2.176	0.0309	*
Year2020	0.079	0.078	1.009	0.3144	
Year2021	0.081	0.080	1.017	0.3105	
Year2022	0.259	0.079	3.303	0.0012	**
Year2023	0.291	0.079	3.659	0.0003	***

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 0.02601072)

Null deviance: 14.27 on 215 degrees of freedom

Residual deviance: 4.708 on 181 degrees of freedom

AIC: -141.44

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)
Standardization of CPUE for Splendid Alfonsino (Tokyo Bay Entrance, Chiba Prefecture)

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency
Yohei Kawauchi, Aigo Takeshige, Shingo Watari, Shion Takemura, Kazuhiro Aoki, Hitomi Oyaizu

Summary

Data	Catch and number of landings (day･vessel) data by month for the vertical longline fishery of Splendid Alfonsino in the Tokyo Bay entrance by vessels registered in Chiba Prefecture. Fishing operation location data are not included. Water temperature, direction, and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard's Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day･vessel)
Data availability period	2000-2023
Period used for standardization	2000-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical values as fixed effects) Water temperature, current speed, the latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, latitudinal difference of the Kuroshio northern edge between longitudes 138°E and 139°E, latitudinal difference in the northern edge of the Kuroshio between longitudes 139°E and 140°E
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects

Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.
Results of CPUE standardization	The standardized CPUE decreased from 2007 to 2012 and increased in 2013. Since then, the standardized CPUE has fluctuated significantly and has remained at a low level since 2019. However, since 2021, there has been a gradual upward trend, with an increase observed in 2023 compared to the previous year. The trend is similar for nominal CPUE, but standardized CPUE was significantly higher in 2000, 2003-2006, and 2018. In many other years, the nominal CPUE was higher.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We used “year”, “season”, ”area”, and “the distance to the Kuroshio axis (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised by fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds and entire habitat of the stock) (Watari et al., 2023). As the results of the estimation using data from the Katsuura district of Chiba Prefecture showed generally acceptable model diagnostic results, demonstrating correction of the lower CPUE due to the effects of the Kuroshio path and current speed in the fishing grounds, it was decided to use the yearly trend derived from this model as one of the tuning indices for the VPA of the Splendid Alfonsino of Pacific Japan.

This fiscal year, as in the previous fiscal year, the CPUE standardization model for vessels registered in Chiba Prefecture vessels operating at the Tokyo Bay entrance has been updated by adding the most recent data from the current fiscal year.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Tokyo Bay Entrance of Chiba Prefecture, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day・vessel) and does not include fishing operation location data. The standardization period was 2000-2023, and all records were used for the analysis.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Tokyo Bay Entrance, the latitude of the Kuroshio northern edge at 140°E (Lat_140) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) was calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were used as indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. As a result, since vessels registered in Chiba Prefecture frequently conduct fishing operations on the eastern side of Nojimazaki at the Tokyo Bay entrance, grids 33 and 34 in Fig. 1 were selected as the fishing grounds for analysis. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Direcfct) after monthly averaging. For current direction and current speed, the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.

Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated of the effects of environmental variables on the CPUE.

Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_400 +
Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_400 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_400 + Direcfct_Bottom +
Lat_140 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available. The collection and organization of more detailed data such as record by and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike's Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plots, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Quarter + Lat138_139 + Lat139_140

For the Tokyo Bay Entrance area, as a result of the model selection process using an exhaustive search based on AIC, 30 models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. Other models within the minimum AIC+2 range suggested that many models consistently included factors such as Kuroshio intrusion, flow direction, and flow velocity. Moreover, explanatory variables related to the influence of Kuroshio and the flow within the fishing grounds were more likely to be selected. The CPUE responses to each of the selected explanatory variables in the best model (Fig.

4) also detected changes in the CPUE caused by fluctuations in the strength of Kuroshio intrusion.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. The standardized CPUE showed a decreasing trend from 2007 to 2012 but increased in 2013. Since then, the standardized CPUE has fluctuated significantly but has remained at a low level since 2019. However, since 2021, there has been a gradual upward trend, with an increase observed in 2023 compared to the previous year. The trend is similar for nominal CPUE, but standardized CPUE was significantly higher in 2000, 2003-2006, and 2018. In many other years, the nominal CPUE was higher.

3.2 Comparison with the Previous Fiscal Year’s Results

As in the previous fiscal year, the latitude difference between the northern edge of the Kuroshio at longitudes 139 to 140 degrees east and the seasonal effect was included in the best model. On the other hand, the latitude difference between the northern edge of the Kuroshio at longitudes 138 to 139 degrees, which was not included in the previous fiscal year’s best model, has been included this year. However, the 0 m current speed that was included in the previous fiscal year has been excluded this year. However, in any of the given years, many models within the minimum AIC+2 range include these flow velocities and the latitude differences of the Kuroshio northern edge. Moreover, since the changes in the annual trends of standardized CPUE based on the best model are also small, it can be concluded that the addition of one year of data did not result in significant changes in the model estimation results.

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Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction					Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Sea-son	Year	df	logLik	AIC	delta
	0	100	200	400	Bottom	140°E	138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom						
4.74					+		0.27	0.36												+	+	35	-409.1	888.2	0.0
5.10					+		0.31	0.41	0.15											+	+	36	-408.1	888.3	0.0
5.20					+		0.28	0.35	0.15	-0.79										+	+	37	-407.4	888.8	0.5
4.83					+		0.24	0.31		-0.79										+	+	36	-408.4	888.8	0.6
12.68					+	-0.23	0.26	0.31	0.25											+	+	37	-407.5	888.9	0.7
5.11			+				0.29	0.42	0.17											+	+	38	-406.7	889.3	1.1
4.67							0.26	0.38												+	+	30	-414.7	889.3	1.1
4.90							0.31	0.42	0.15											+	+	31	-413.7	889.4	1.2
4.84					+		0.27	0.35						-5.25						+	+	36	-408.8	889.5	1.3
5.20					+		0.32	0.40	0.15					-5.20						+	+	37	-407.8	889.5	1.3
4.83			+				0.24	0.38												+	+	37	-407.8	889.7	1.4
5.18					+		0.30	0.37	0.15		-0.81									+	+	37	-407.9	889.7	1.5
4.82					+		0.25	0.33			-0.80									+	+	36	-408.9	889.7	1.5
4.05					+		0.32	0.43	0.16										0.14	+	+	37	-407.9	889.8	1.5
4.17					+		0.32	0.42	0.15									0.13		+	+	37	-407.9	889.9	1.6
3.83					+		0.28	0.38											0.12	+	+	36	-408.9	889.9	1.6
3.88					+		0.27	0.38										0.12		+	+	36	-409.0	889.9	1.7
5.05					+		0.31	0.41	0.16			1.45								+	+	37	-408.0	890.0	1.7
11.12					+	-0.18	0.25	0.28	0.23	-0.64										+	+	38	-407.0	890.0	1.8
4.49					+		0.32	0.43	0.16								0.05			+	+	37	-408.0	890.0	1.8
4.69					+		0.27	0.37				1.22								+	+	36	-409.0	890.0	1.8
4.76							0.23	0.33		-0.75										+	+	31	-414.0	890.1	1.8
5.00							0.28	0.37	0.15	-0.75										+	+	32	-413.1	890.1	1.9
4.80					+		0.32	0.42	0.16							0.02				+	+	37	-408.1	890.2	1.9
4.83					+		0.27	0.36							-0.01					+	+	36	-409.1	890.2	2.0
11.99					+	-0.24	0.27	0.32	0.26										0.17	+	+	38	-407.1	890.2	2.0
4.52					+		0.27	0.37									0.02			+	+	36	-409.1	890.2	2.0
4.65					+		0.27	0.37								0.01				+	+	36	-409.1	890.2	2.0
5.00					+	-0.01	0.27	0.36												+	+	36	-409.1	890.2	2.0
4.75					+		0.27	0.36					-0.25							+	+	36	-409.1	890.2	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2000	1.22	1.61	1.11	2.11	0.16
2001	2.56	2.06	1.02	3.78	0.33
2002	0.71	0.62	0.27	1.10	0.33
2003	1.31	1.47	0.82	2.39	0.26
2004	0.93	1.44	0.82	2.55	0.31
2005	1.28	2.11	1.46	2.76	0.17
2006	1.90	2.22	1.48	2.98	0.17
2007	1.28	1.34	0.75	2.02	0.24
2008	1.35	1.30	0.71	2.21	0.29
2009	0.75	0.60	0.34	0.91	0.24
2010	0.43	0.45	0.31	0.60	0.17
2011	0.73	0.48	0.25	0.85	0.33
2012	0.41	0.32	0.18	0.59	0.35
2013	0.61	0.47	0.22	0.78	0.31
2014	0.69	0.56	0.29	0.96	0.30
2015	1.20	1.09	0.67	1.61	0.23
2016	1.77	1.22	0.33	2.58	0.47
2017	0.69	0.32	0.13	0.81	0.48
2018	1.06	2.48	1.33	3.91	0.27
2019	0.52	0.35	0.12	0.93	0.56
2020	0.18	0.15	0.09	0.23	0.25
2021	0.36	0.37	0.17	0.73	0.38
2022	0.92	0.35	0.13	0.82	0.48
2023	1.13	0.64	0.25	1.24	0.39

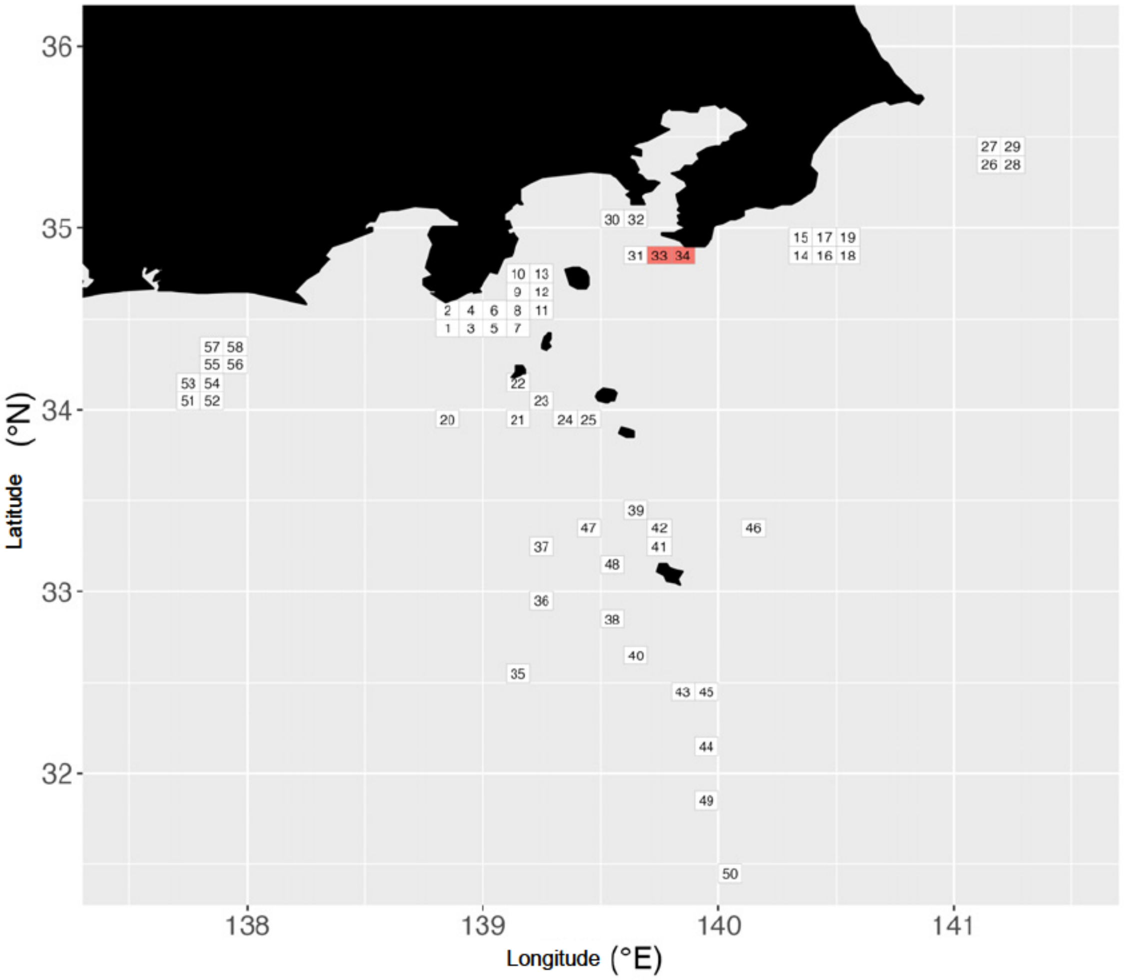

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values - Data extracted for 0.1° grid units of latitude and longitude

For the Tokyo Bay Entrance, grids 33-34 were used.

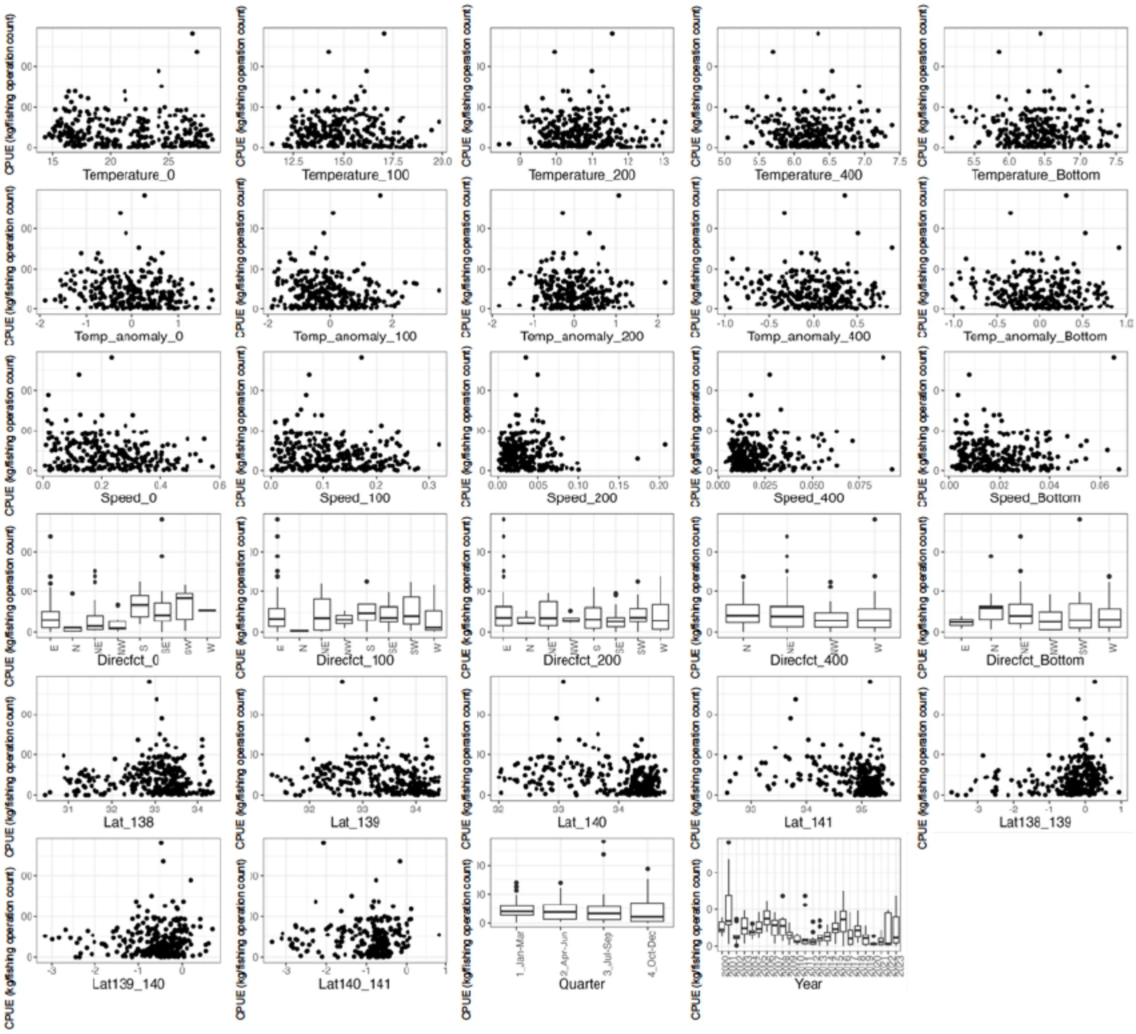

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

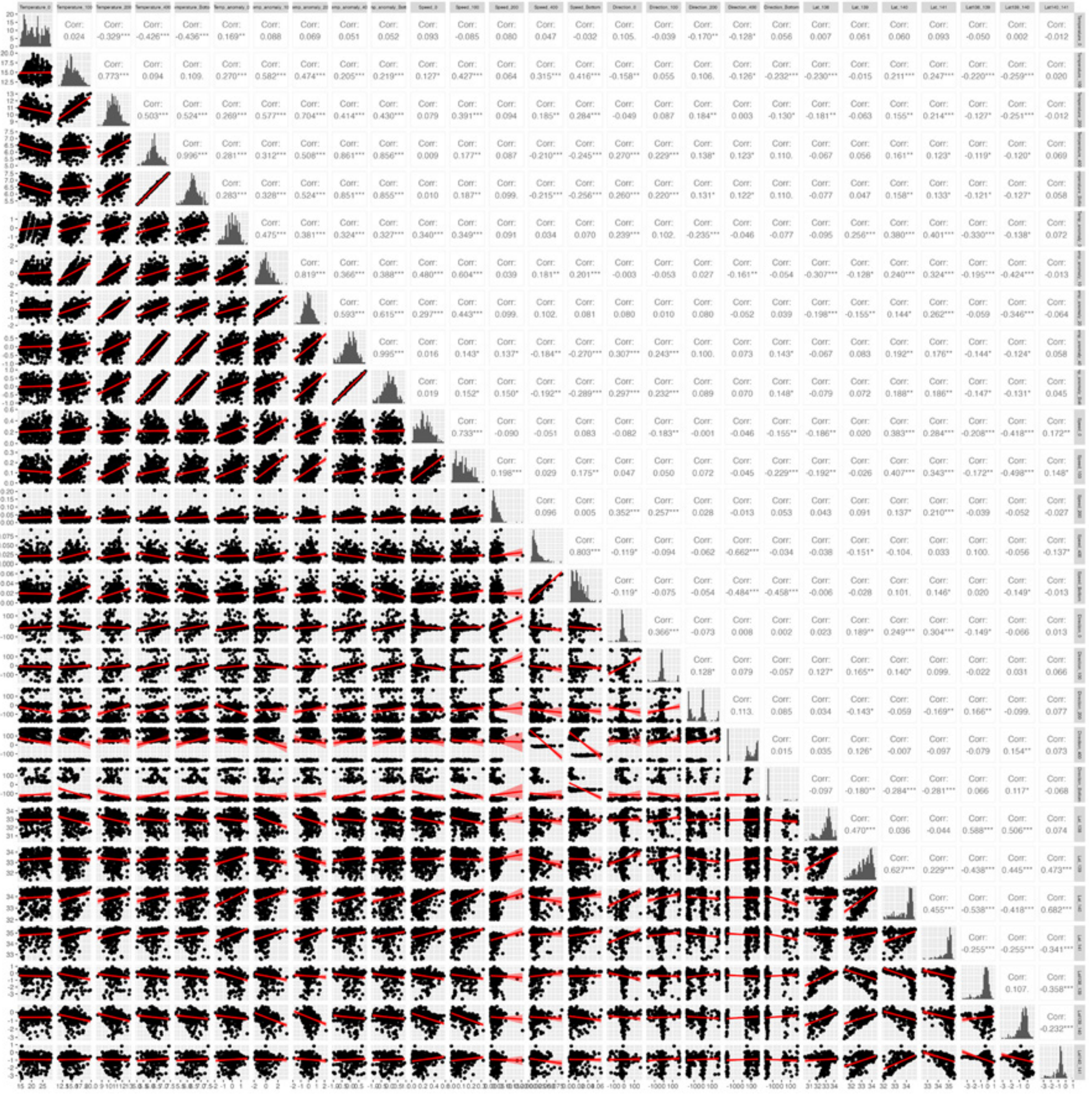

Fig. 3. Correlation between the marine environmental data used in the standardization model

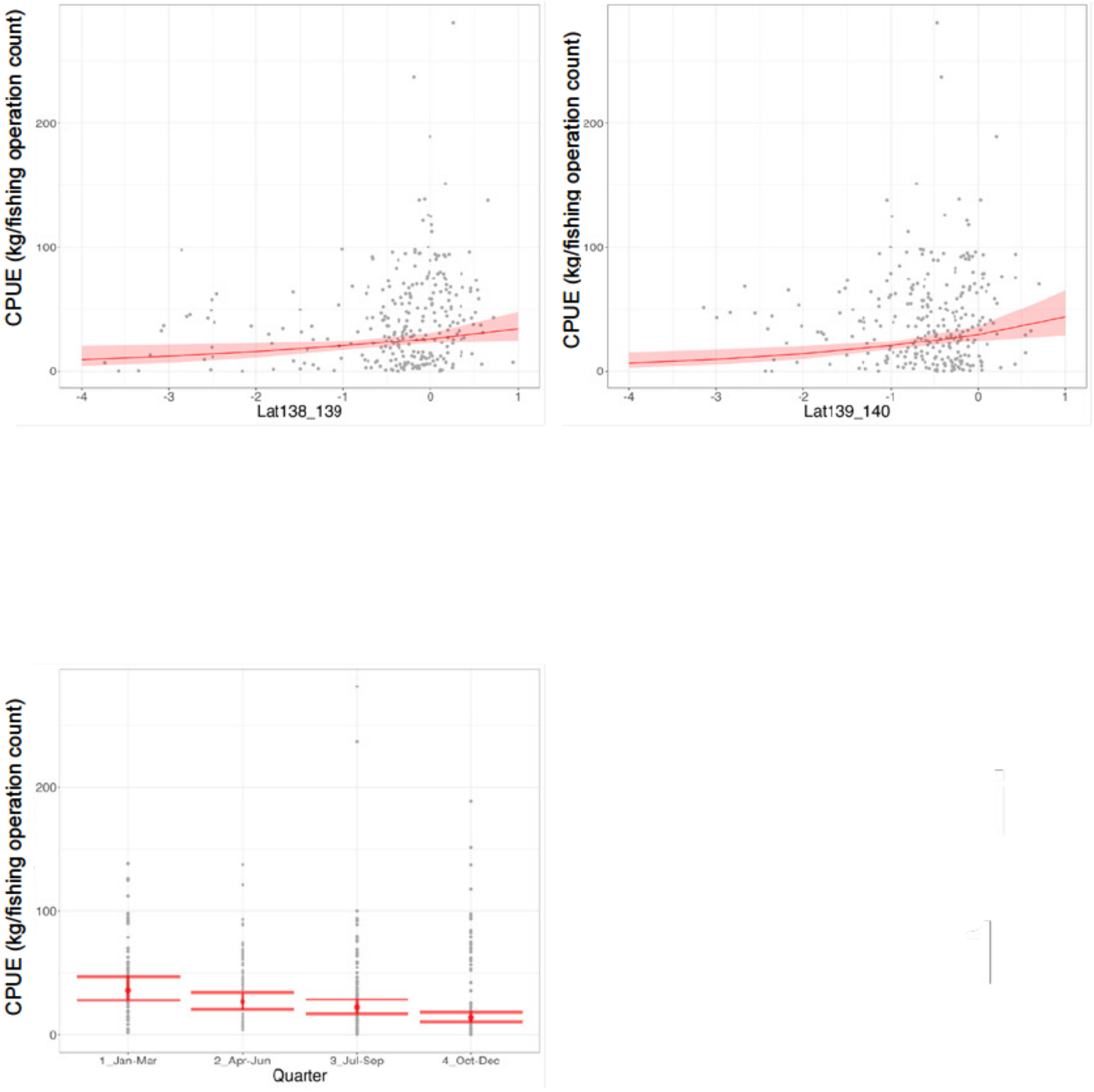

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

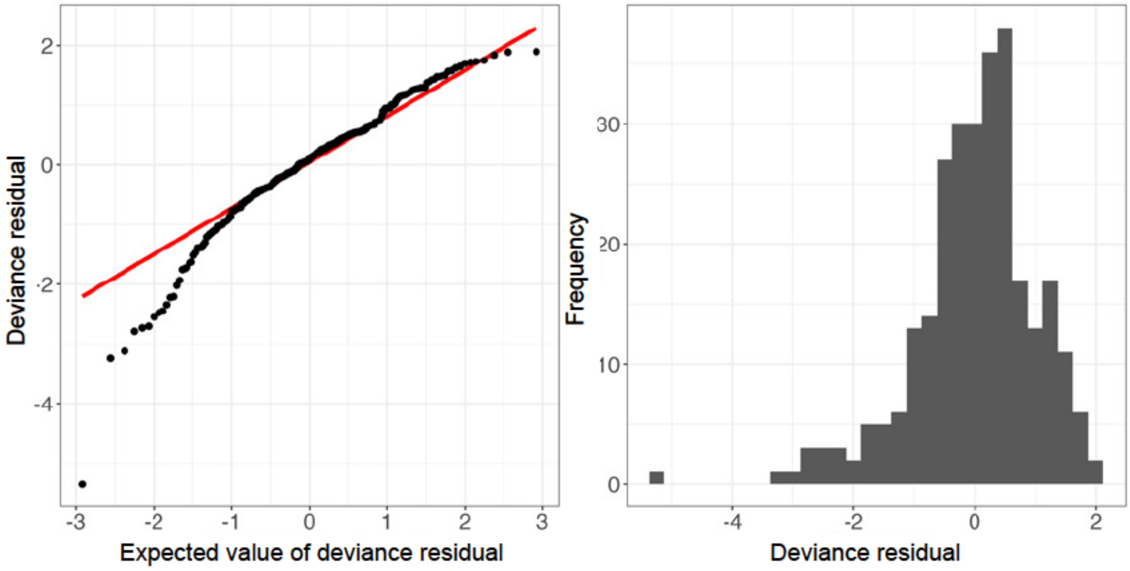

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

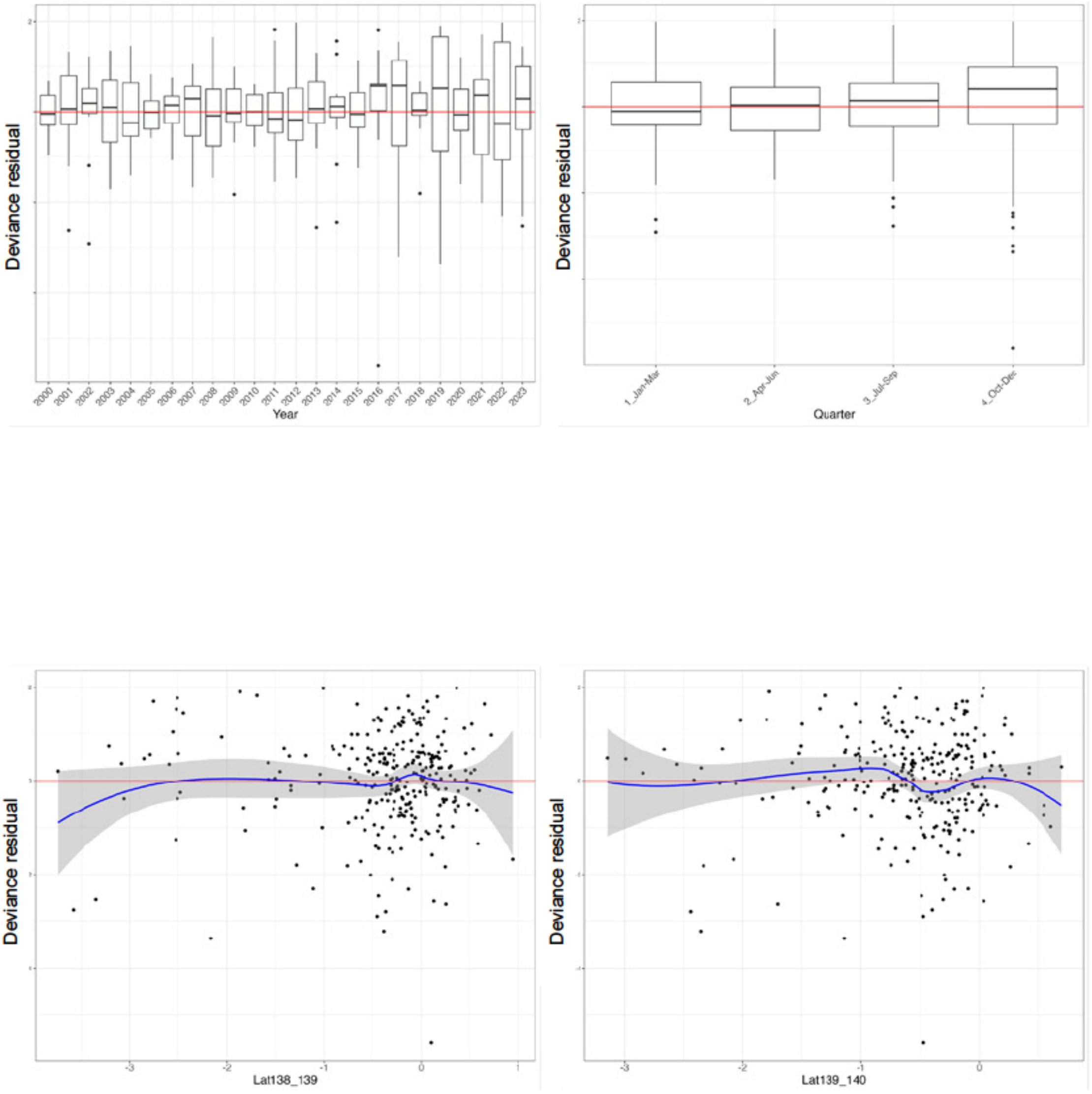

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Lat138_139 and Lat139_140 represent fitted smoothing curves (loess) and their 95% confidence intervals.

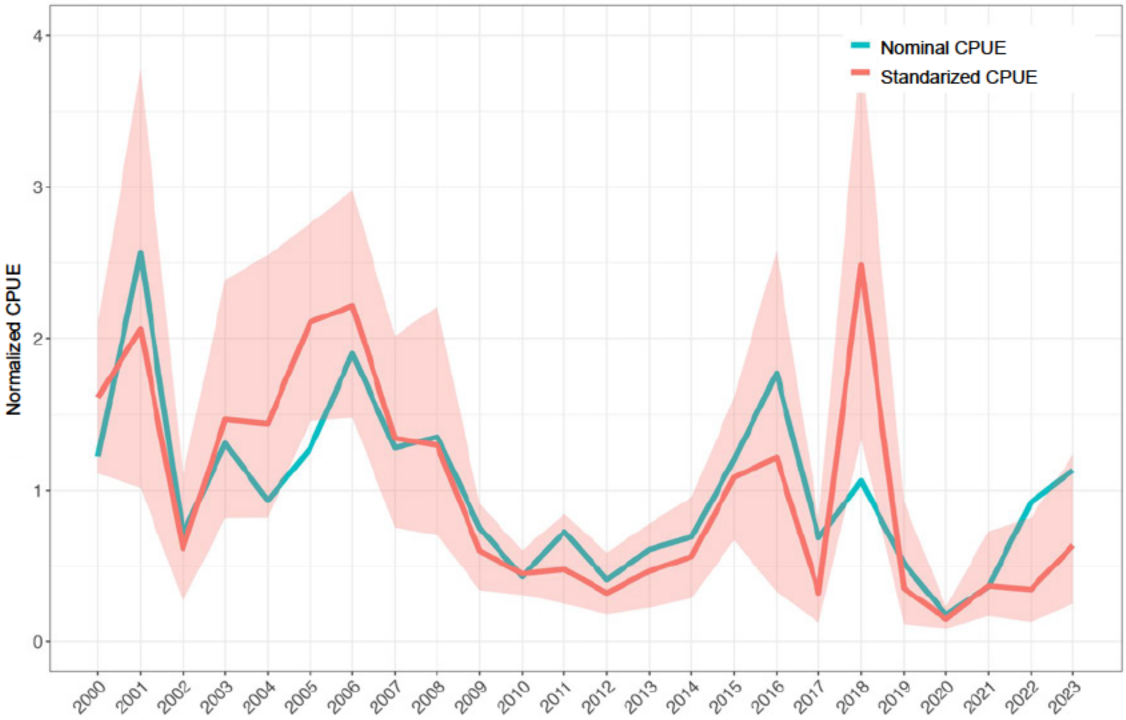

Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Lat138_139 + Lat139_140 + Quarter + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	4.667	0.355	13.153	0.0000	***
Lat138_139	0.263	0.109	2.425	0.0160	*
Lat139_140	0.381	0.122	3.127	0.0020	**
Quarter2_Apr-Jun	-0.306	0.187	-1.639	0.1025	
Quarter3_Jul-Sep	-0.491	0.184	-2.667	0.0081	**
Quarter4_Oct-Dec	-0.940	0.186	-5.050	0.0000	***
Year2001	0.245	0.462	0.531	0.5960	
Year2002	-0.964	0.462	-2.087	0.0379	*
Year2003	-0.094	0.451	-0.209	0.8349	
Year2004	-0.113	0.469	-0.242	0.8091	
Year2005	0.267	0.455	0.586	0.5581	
Year2006	0.318	0.451	0.705	0.4813	
Year2007	-0.182	0.450	-0.405	0.6860	
Year2008	-0.218	0.453	-0.481	0.6310	
Year2009	-0.990	0.456	-2.171	0.0308	*
Year2010	-1.280	0.461	-2.777	0.0059	**
Year2011	-1.217	0.450	-2.705	0.0073	**
Year2012	-1.609	0.450	-3.574	0.0004	***
Year2013	-1.242	0.454	-2.736	0.0067	**
Year2014	-1.053	0.451	-2.333	0.0204	*
Year2015	-0.396	0.453	-0.875	0.3824	
Year2016	-0.280	0.451	-0.622	0.5343	
Year2017	-1.609	0.449	-3.581	0.0004	***
Year2018	0.432	0.482	0.896	0.3709	
Year2019	-1.518	0.496	-3.063	0.0024	**

	Estimate	Standard Error	z value	Pr(>|z|)	
Year2020	-2.372	0.457	-5.194	0.0000	***
Year2021	-1.474	0.470	-3.137	0.0019	**
Year2022	-1.540	0.459	-3.356	0.0009	***
Year2023	-0.930	0.467	-1.990	0.0477	*

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 1.209321)

Null deviance: 514.9 on 283 degrees of freedom

Residual deviance: 308.4 on 255 degrees of freedom

AIC: 889.34

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)
Standardization of CPUE for Splendid Alfonsino (Tokyo Bay Entrance, Kanagawa Prefecture)

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency
Yohei Kawauchi, Aigo Takeshige, Shingo Watari, Shion Takemura, Kazuhiro Aoki, Hitomi Oyaizu

Summary

Data	Catch and number of landings (day・vessel) data by month for the vertical longline fishery of Splendid Alfonsino in the Tokyo Bay entrance by Kanagawa Prefecture-registered vessels. Fishing operation location data are not included. Water temperature, direction, and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard's Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day・vessel)
Data availability period	2000 to 2023 (Only January to May in 2023)
Period used for standardization	2000 to 2023 (Only January to May in 2023)
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical, value as fixed effects) Water temperature, current speed, the latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, current velocity at 100 m depth layer,
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects

Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.
Results of CPUE standardization	The standardized CPUE decreased significantly in 2002 and further decreased from 2008 to 2012. Since 2012, standardized CPUE has remained at a low level, although there have been some increases and decreases. It has remained at a low level since 2020; however, standardized CPUE increased for two consecutive years in 2022 and 2023. There were no significant differences between the values of standardized CPUE and nominal CPUE; however, standardized CPUE was noticeably higher from 2000 to 2001, 2003 to 2008 and 2018.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catching efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We used “year”, “season”, ”area”, and “the distance to the Kuroshio axis (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised by fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were sepalaely developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds and entire habitat of the stock) (Watari et al., 2023). As a result, it was determined that the standardized CPUE based on data from vessels registered in Kanagawa Prefecture operating at the Tokyo Bay entrance gave more consideration to the influence of environmental factors. Since the model diagnostic results were generally good, it was decided to introduce it as one of the tuning indices for the VPA.

This fiscal year, as in the previous fiscal year, the CPUE standardization model for vessels registered in Kanagawa Prefecture vessels operating at the Tokyo Bay entrance has been updated by adding the most recent data from the current fiscal year.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Tokyo Bay Entrance of

Kanagawa Prefecture, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day･vessel) and does not include fishing operation location data. The standardization period was 2000-2023, and all records were used for the analysis. However, the fishing effort by vessels registered in Kanagawa Prefecture operating at the Tokyo Bay entrance has been declining in recent years, and no fishing operations were conducted at the Tokyo Bay entrance from June to December 2023.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Tokyo Bay Entrance, the latitude of the Kuroshio northern edge at 140°E (Lat_140) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) was calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were used as an indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. As a result, since vessels registered in Kanagawa Prefecture frequently conduct fishing operations on the western side of Nojimazaki at the Tokyo Bay entrance, grids 31 and 33 in Fig. 1 were selected as the fishing grounds for analysis. However, since the depth at grids 31 and 33 is shallow, only the reanalysis values of water temperature, current direction, and current velocity at depth zones of 0 m, 100 m, 200 m and the bottom layer were used. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Direcfct) after monthly averaging. For current direction and current speed, the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.

Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.

Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_Bottom +
Lat_140 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike’s Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The

best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plot, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Quarter + Speed_100

For the Tokyo Bay Entrance area, as a result of the model selection process using an exhaustive search based on AIC, 18 models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. Other models within the minimum AIC+2 range suggested that, in addition to the explanatory variables selected in the best model, Kuroshio intrusion and water temperature effect were also selected in many other models, demonstrating a tendency to select explanatory variables associated with the influence of Kuroshio, and flow and water temperature within the fishing ground. The CPUE responses to each of the selected explanatory variables in the best model (Fig. 4) also detected changes in the CPUE influenced by the current velocity within the fishing grounds.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. The standardized CPUE decreased significantly in 2002 and further decreased from 2008 to 2012. Since 2013, standardized CPUE has remained at a low level, although there have been some increases and decreases. It has remained at a low level since 2020; however, standardized CPUE increased for two consecutive years in 2022 and 2023. Although the long-term trend of nominal CPUE was similar to standardized CPUE, the standardized CPUE was significantly higher from 2000 to 2001, 2003 to 2008 and in 2018.

As described above, no fishing operations were conducted by vessels registered in Kanagawa Prefecture from June onwards in 2023, raising concerns that the unavailability of data for more than half a year may increase the uncertainty of the estimation results. The 95% confidence intervals for the estimated value of 2023 indicate that the CPUE had increased to at least the same level as it was before 2009 when it was at a higher level (Fig. 7, Table 2). This suggests that such uncertainty may have actually been reflected in the analysis results. Since the fishing effort of fishing operations has continued to decline in recent years, it is necessary to continue monitoring changes in data quality and the validity of the analysis results.

3.2 Comparison with the Previous Fiscal Year’s Results

The explanatory variables selected for this fiscal year’s best model were the same as those of the previous fiscal year, and there were no significant differences from the previous year in the standardized CPUE trends derived from the best model.

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Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-

37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

Watari, S. and Hanzawa, Y. (2022) FY 2021 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FY 2021 Fisheries Stock Assessment in the Waters around Japan, Japan Fisheries Research and Education Society, Fisheries Agency. FRA-SA2021-RC02-2. https://abchan.fra.go.jp/wpt/wp-content/uploads/2021/details_2021_37.pdf

Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction				Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed				Water temperature				Sea-son	Year	df	logLik	AIC	delta
	0	100	200	Bottom	140°E	138-139	139-140	140-141	0	100	200	Bottom	0	100	200	Bottom						
7.45	+					0.18			-1.78						-0.21			+	35	-301.7	673.3	0.0
7.00	+					0.16			-2.06							-0.24	+	+	38	-298.9	673.7	0.4
4.59										-3.12							+	+	29	-308.0	673.9	0.6
6.69	+					0.15			-1.76						-0.15		+	+	38	-299.0	674.1	0.8
6.00										-3.04						-0.17	+	+	30	-307.1	674.3	1.0
7.19	+								-2.12							-0.26	+	+	37	-300.2	674.3	1.0
6.93	+								-1.78						-0.17		+	+	37	-300.2	674.5	1.2
7.76	+								-1.84						-0.23			+	34	-303.4	674.7	1.4
6.51	+					0.17			-1.33					-0.1				+	35	-302.4	674.8	1.5
7.00	+					0.17				-2.32					-0.17			+	35	-302.4	674.8	1.5
4.93	+					0.18			-1.96								+	+	37	-300.5	675.0	1.7
4.59						0.09				-2.92							+	+	30	-307.5	675.0	1.7
9.00	+				-0.05	0.16			-1.69						-0.20			+	36	-301.6	675.1	1.8
5.49										-2.85					-0.08		+	+	30	-307.6	675.1	1.8
6.66	+					0.14				-2.68						-0.20	+	+	38	-299.6	675.2	1.9
6.83	+									-2.86						-0.22	+	+	37	-300.6	675.3	1.9
7.45	+					0.18		0.01	-1.78						-0.21			+	36	-301.7	675.3	2.0
7.45	+					0.18	0		-1.78						-0.21			+	36	-301.7	675.3	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2000	1.80	1.98	1.43	2.57	0.15
2001	4.06	4.44	3.13	5.91	0.16
2002	1.18	0.99	0.59	1.55	0.25
2003	1.50	1.59	0.91	2.45	0.25
2004	0.84	1.14	0.83	1.49	0.16
2005	1.76	2.00	1.29	2.94	0.21
2006	1.18	1.32	0.98	1.64	0.13
2007	1.42	1.65	1.18	2.29	0.17
2008	1.28	1.43	0.87	2.15	0.22
2009	1.44	1.10	0.69	1.77	0.24
2010	0.27	0.33	0.21	0.48	0.21
2011	1.05	0.71	0.42	1.34	0.33
2012	0.26	0.18	0.09	0.39	0.41
2013	0.23	0.19	0.10	0.36	0.35
2014	0.36	0.27	0.13	0.49	0.34
2015	0.33	0.37	0.24	0.51	0.19
2016	0.88	0.76	0.43	1.21	0.26
2017	0.51	0.40	0.16	0.70	0.36
2018	0.75	1.05	0.80	1.30	0.12
2019	0.38	0.36	0.22	0.57	0.26
2020	0.39	0.31	0.15	0.55	0.35
2021	0.29	0.28	0.16	0.44	0.25
2022	0.72	0.49	0.17	1.07	0.45
2023	1.12	0.68	0.22	1.83	0.53

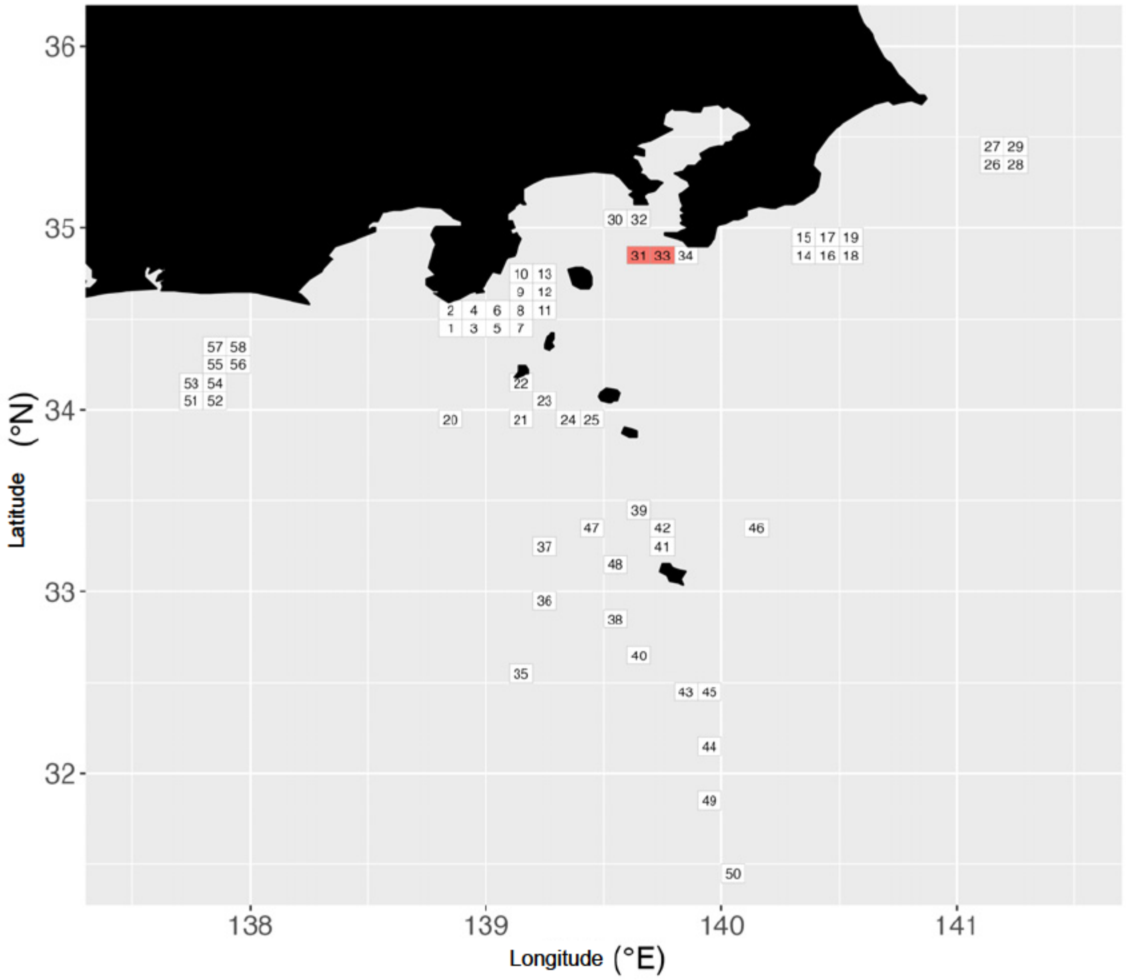

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values - Data extracted for 0.1° grid units of latitude and longitude

For the Tokyo Bay Entrance, grids 31-33 were used.

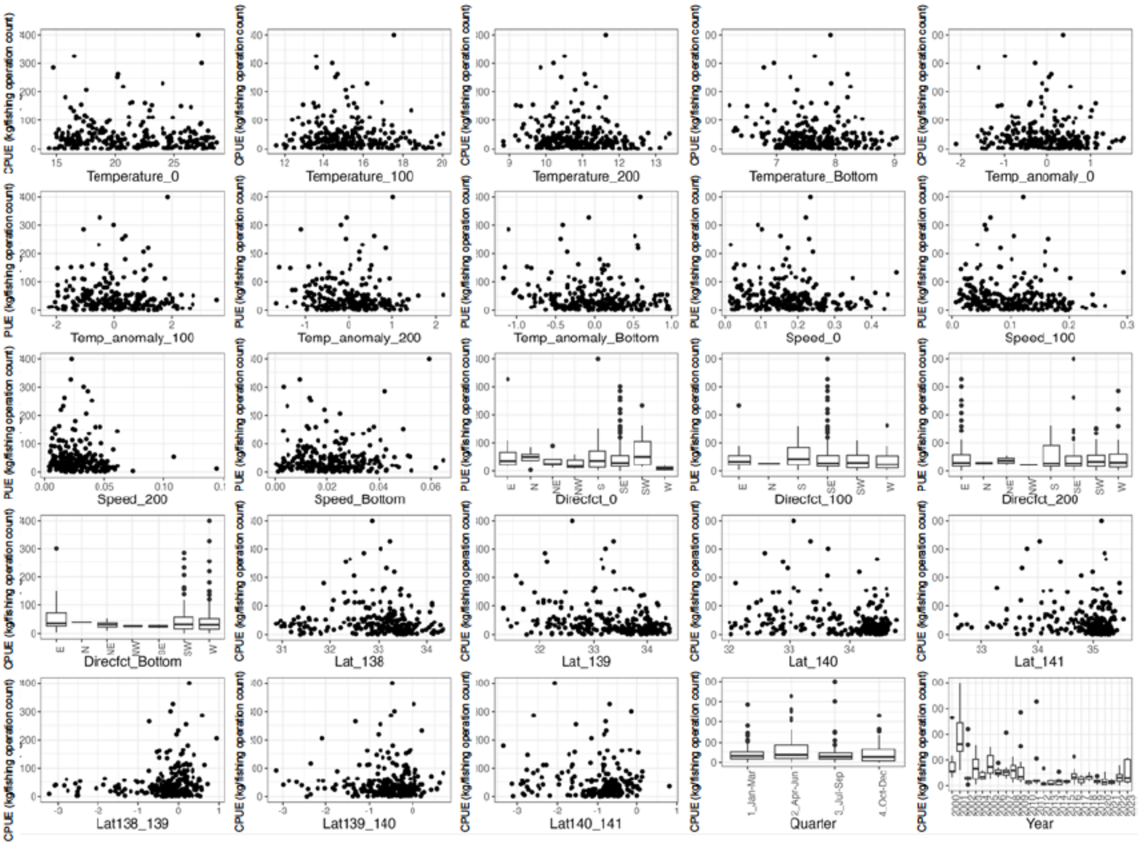

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

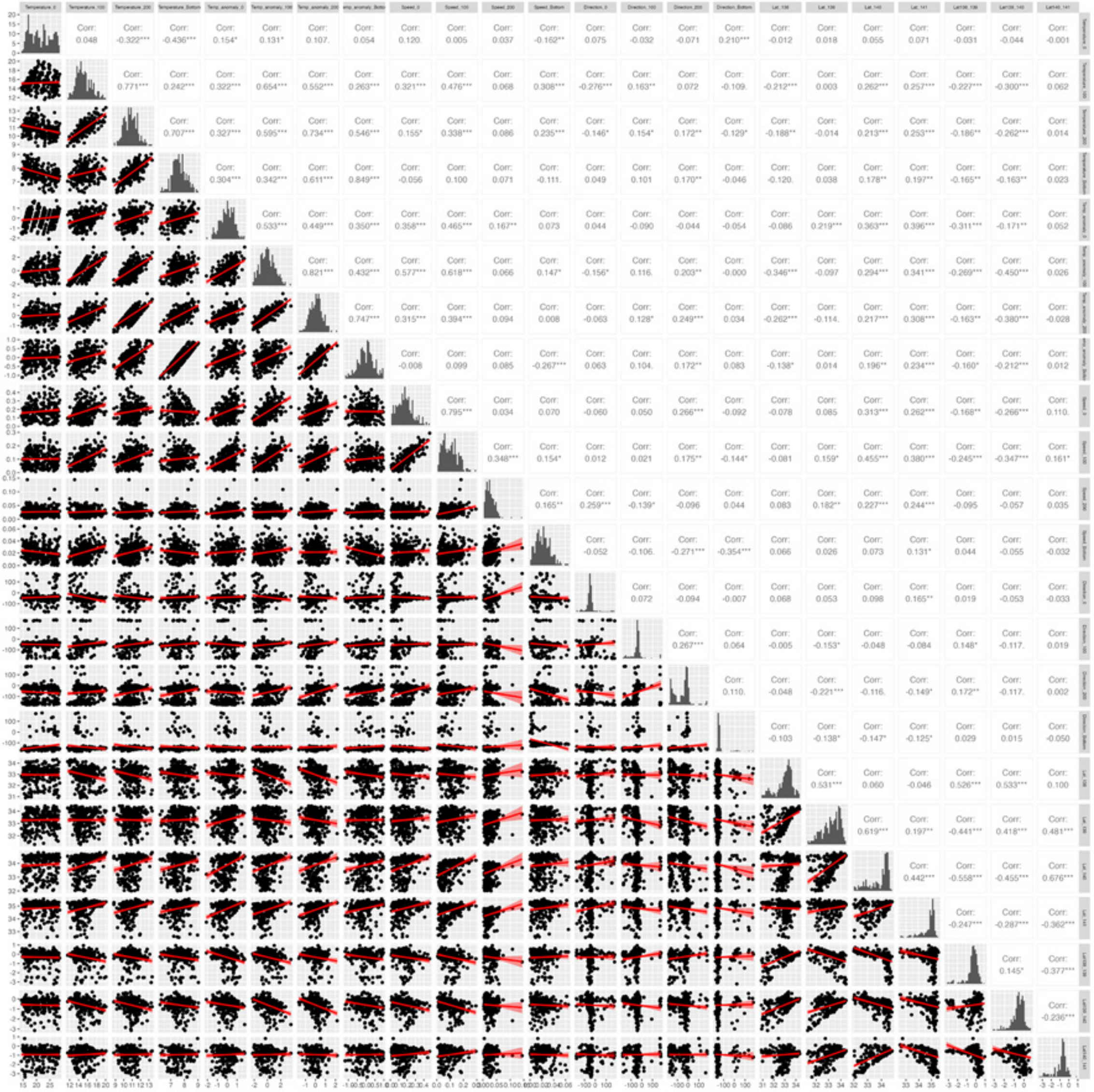

Fig. 3. Correlation between the marine environmental data used in the standardization model

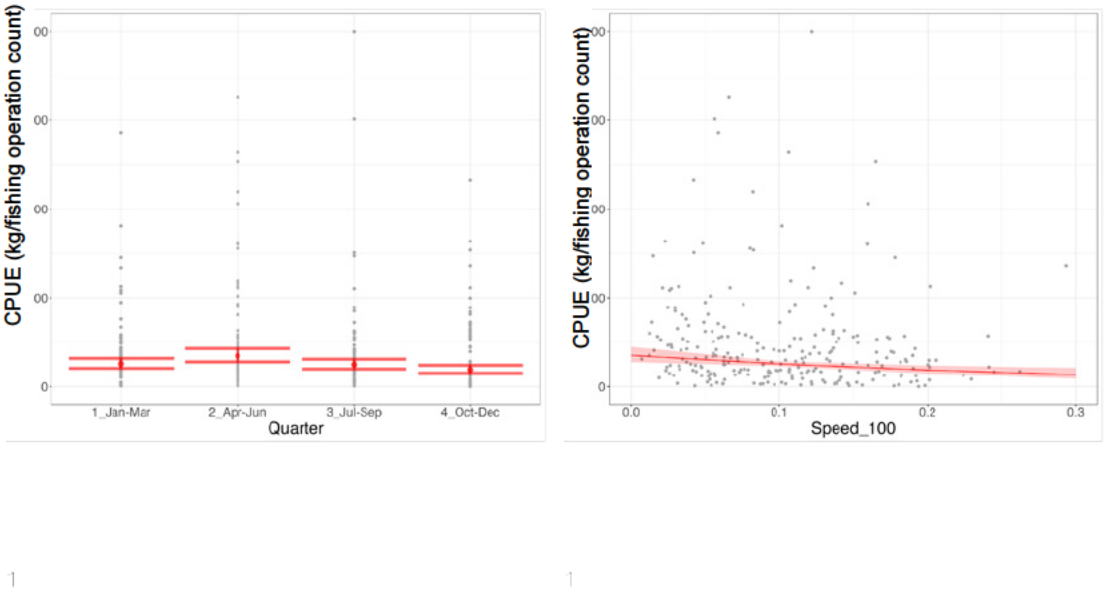

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

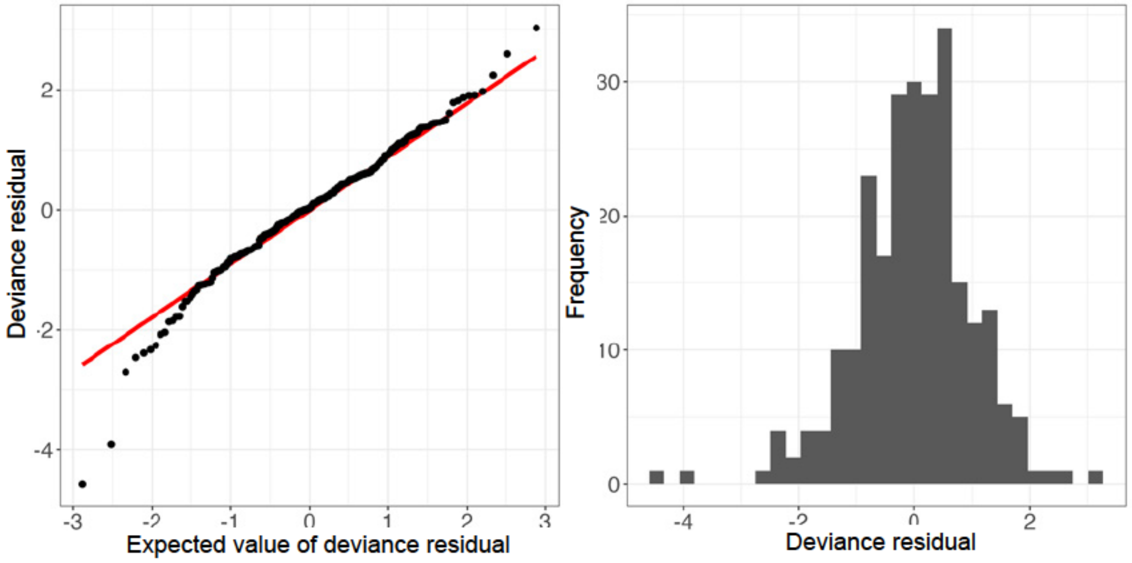

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

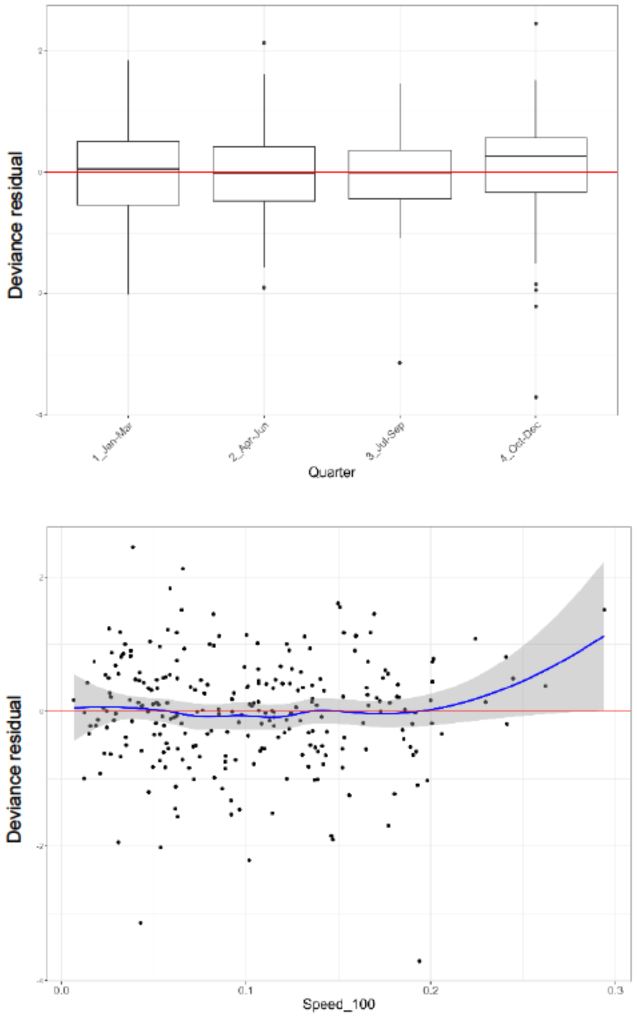

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Speed_100 represent fitted smoothing curves (loess) and their 95% confidence intervals.

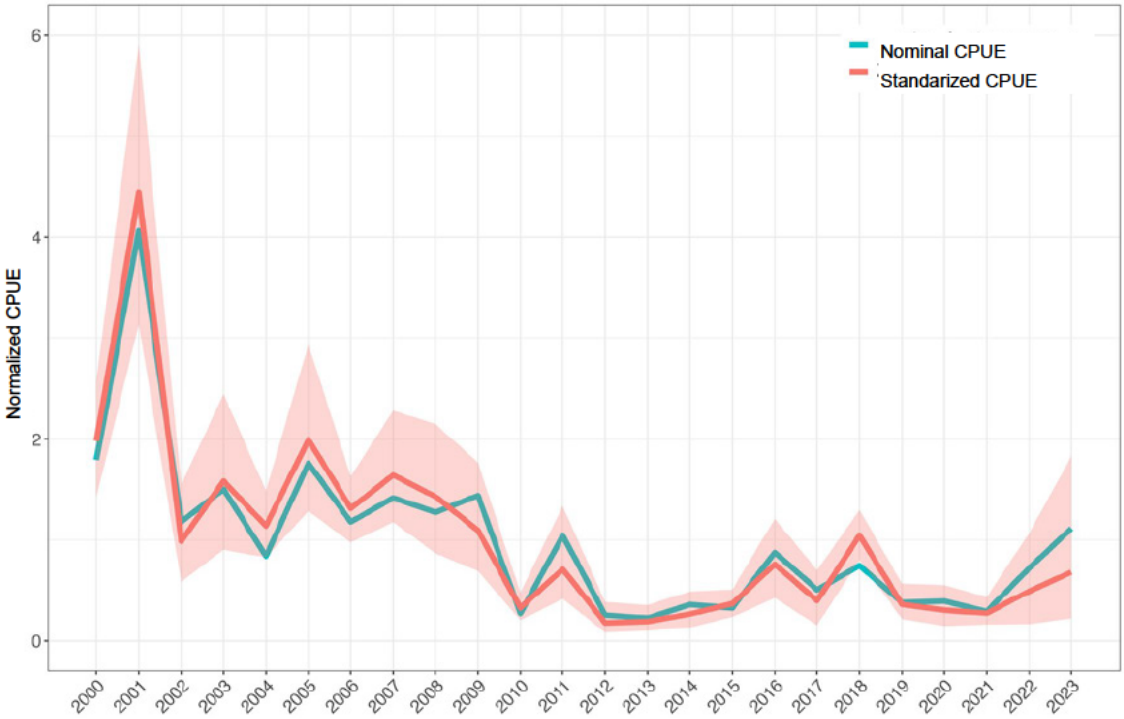

Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Quarter + Speed_100 + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	4.595	0.285	16.113	0.0000	***
Quarter2_Apr-Jun	0.293	0.152	1.923	0.0558	.
Quarter3_Jul-Sep	-0.035	0.153	-0.229	0.8194	
Quarter4_Oct-Dec	-0.289	0.159	-1.812	0.0713	.
Speed_100	-3.116	1.067	-2.921	0.0038	**
Year2001	0.806	0.360	2.238	0.0262	*
Year2002	-0.696	0.362	-1.924	0.0557	.
Year2003	-0.223	0.354	-0.630	0.5292	
Year2004	-0.553	0.354	-1.561	0.1200	
Year2005	0.007	0.352	0.019	0.9845	
Year2006	-0.410	0.354	-1.157	0.2483	
Year2007	-0.186	0.370	-0.504	0.6150	
Year2008	-0.325	0.353	-0.923	0.3571	
Year2009	-0.592	0.353	-1.678	0.0947	.
Year2010	-1.798	0.361	-4.977	0.0000	***
Year2011	-1.023	0.355	-2.885	0.0043	**
Year2012	-2.401	0.364	-6.603	0.0000	***
Year2013	-2.327	0.381	-6.111	0.0000	***
Year2014	-2.004	0.352	-5.691	0.0000	***
Year2015	-1.679	0.360	-4.662	0.0000	***
Year2016	-0.957	0.362	-2.647	0.0087	**
Year2017	-1.601	0.360	-4.447	0.0000	***
Year2018	-0.638	0.363	-1.758	0.0801	.
Year2019	-1.700	0.394	-4.312	0.0000	***
Year2020	-1.868	0.369	-5.056	0.0000	***

	Estimate	Standard Error	z value	Pr(>|z|)	
Year2021	-1.973	0.394	-5.007	0.0000	***
Year2022	-1.390	0.396	-3.512	0.0005	***
Year2023	-1.066	0.465	-2.291	0.0229	*

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 0.7436515)

Null deviance: 364 on 253 degrees of freedom

Residual deviance: 168.1 on 226 degrees of freedom

AIC: 673.92

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)
Standardization of CPUE for Splendid Alfonsino (Kozushima Island Area, Tokyo Metropolis)

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency
Yohei Kawauchi, Aigo Takeshige, Shingo Watari, Shion Takemura, Kazuhiro Aoki, Hitomi Oyaizu

Summary

Data	Catch and number of landings (day･vessel) data by month for vertical longline fishery of Splendid Alfonsino in Kozushima Island Area, Tokyo Metropolis. Fishing operation location data are not included. Water temperature, direction and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard’s Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day･vessel)
Data availability period	2005-2023
Period used for standardization	2005-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical value as fixed effects) Water temperature, current speed, the latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, the water temperature at the 100 m depth layer, the latitudinal difference in the northern edge of the Kuroshio between longitudes 140°E and 141°E
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects

Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.
Results of CPUE standardization	The standardized CPUE decreased from 2008 to 2013. The trend showed an increase up to 2020. Although it slightly decreased from 2021, it remained at roughly the same level in 2023 as it was in 2020. Although the long-term trend of nominal CPUE was similar to standardized CPUE, the standardized CPUE was higher from 2018 onwards.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We uesd “year”, “season”, “area” and the distance to the Kuroshio axis (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised by fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds and entire habitat of the stock) (Watari et al., 2023). As the results of the estimation using data from the Kozushima Island Area of Tokyo Metropolis showed generally acceptable model diagnostic results, demonstrating correction of the lower CPUE due to the effects of the Kuroshio path and water temperature in the fishing grounds, it was decided to use the yearly trend derived from this model as one of the tuning indices for the VPA of the Splendid Alfonsino of Pacific Japan.

This fiscal year, as in previous fiscal years, the standardization model for the Kozushima Island Area of Tokyo Metropolis has been updated with the most recent data for the current fiscal year.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Kozushima Island area of Tokyo Metropolis, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day･vessel) and does not include fishing operation location data. The standardization period was 2005-2023, and all records were used for the analysis.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Kozushima Island Area, the latitude of the Kuroshio northern edge at 139°E (Lat_139) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) Calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were uesd as indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. For the Kozushima Island Area, grid number 23 in Fig. 1 was selected as fishing grounds for analysis. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables

(Direcfct) after monthly averaging. For current direction and current speed, the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.

Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_400 +
Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_400 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_400 + Direcfct_Bottom +
Lat_139 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.. The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike's Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 rangewith the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plot, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Quarter + Temperature_100 + Lat140_141

For the Kozushima Island Area, as a result of the model selection process using an exhaustive search based on AIC, 10 models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. Other models within the minimum AIC+2 range suggeted that, in addition to the explanatory variables selected in the best model, current speed was also selected in many other models, demonstrating that explanatory variables associated with the influence of the Kuroshio Current and flow and water temperature within the fishing ground tend to be selected as effective variable in many cases. The CPUE responses to each of the selected explanatory variables in the best model (Fig. 4) also suggested changes in the CPUE caused by fluctuations in the strength of Kuroshio intrusion, and water temperature.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. Although the standardized CPUE increased in 2007, it decreased from 2008 to 2013. The trend showed an increase up to 2020. Although it slightly decreased after 2021, it remained at approximately the same level in 2023 as in 2020. Although the long-term trend of nominal CPUE was similar to standardized CPUE, the standardized CPUE was higher from 2018 onwards. In other cases, nominal CPUE was higher, or the difference in values between the indices was minimal.

3.2 Comparison with the Previous Fiscal Year’s Results

The explanatory variables selected for this fiscal year’s best model were the same as those of the previous fiscal year, and there were no significant differences from the previous year in the standardized CPUE trends derived from the best model.

Cited literature

Kuroda, H., Setou, T., Kakehi, S., Ito, S., Taneda, T., Azumaya, T., Inagake, D., Hiroe, Y., Morinaga, K., Okazaki, M., Yokota, T., Okunishi, T., Aoki, K., Shimizu, Y., Hasegawa, D., and Watanabe, T. (2017) Recent advances in Japanese fisheries science in the Kuroshio-Oyashio region through development of the FRA-ROMS ocean forecast system: Overview of the reproducibility of reanalysis products. Open Journal of Marine Science, 7, 62–90.

Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

Watari, S., Hanzawa, Y. (2022) FY 2021 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FY 2021 Fisheries Stock Assessment in the Waters around Japan, Japan Fisheries Research and Education Society, Fisheries Agency. FRA-SA2021-RC02-2. https://abchan.fra.go.jp/wpt/wp-content/uploads/2021/details_2021_37.pdf

Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction					Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Season	Year	df	logLik	AIC	delta
	0	100	200	400	Bottom	139°E	138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom						
4.62									-0.06							-0.02				+	+	25	76.2	-102.3	0.0
4.64				+					-0.06							-0.02				+	+	32	82.7	-101.4	0.9
4.66									-0.06				0.13			-0.03				+	+	26	76.4	-100.9	1.4
4.61							0.01		-0.06							-0.02				+	+	26	76.4	-100.8	1.5
5.05						-0.01			-0.06							-0.02				+	+	26	76.3	-100.6	1.7
4.64									-0.06					0.12		-0.02				+	+	26	76.3	-100.5	1.8
4.60									-0.06	-0.03						-0.02				+	+	26	76.2	-100.4	1.9
4.64									-0.06			0.03				-0.02				+	+	26	76.2	-100.4	1.9
4.62									-0.06		0					-0.02				+	+	26	76.2	-100.3	2.0
4.62								0	-0.06							-0.02				+	+	26	76.2	-100.3	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2005	0.99	0.98	0.87	1.09	0.06
2006	0.96	0.93	0.84	1.05	0.06
2007	1.34	1.29	1.16	1.43	0.05
2008	1.15	1.12	1.03	1.21	0.04
2009	1.29	1.18	1.08	1.29	0.04
2010	1.05	1.06	0.98	1.14	0.04
2011	0.93	0.90	0.72	1.05	0.10
2012	0.81	0.80	0.73	0.88	0.05
2013	0.83	0.79	0.70	0.89	0.06
2014	0.83	0.79	0.71	0.87	0.06
2015	0.93	0.91	0.82	1.00	0.05
2016	0.89	0.86	0.79	0.93	0.04
2017	1.03	1.04	0.96	1.12	0.04
2018	1.00	1.05	0.95	1.16	0.05
2019	1.01	1.09	1.01	1.20	0.04
2020	1.05	1.11	1.01	1.22	0.05
2021	0.99	1.05	0.93	1.20	0.07
2022	0.96	1.02	0.94	1.10	0.04
2023	0.96	1.02	0.92	1.14	0.06

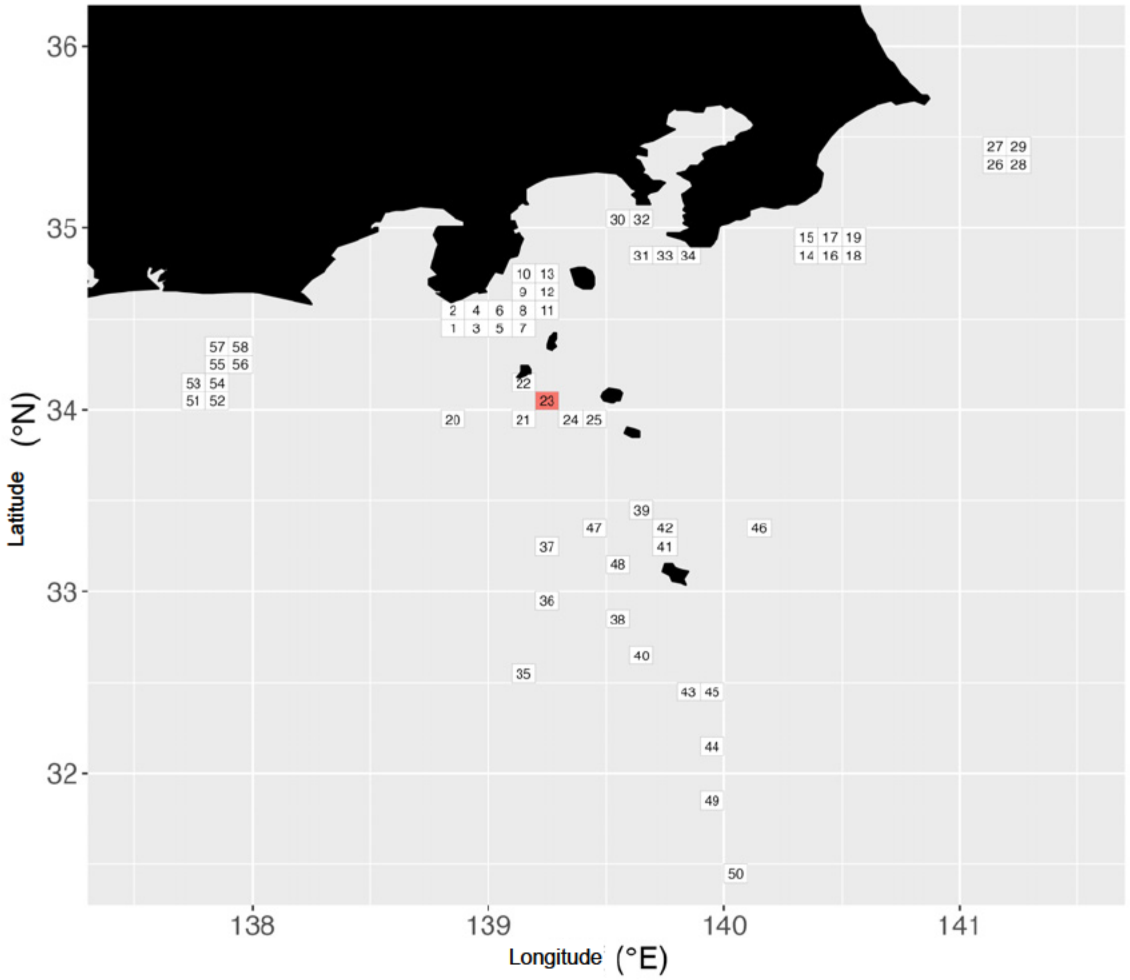

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values - Data extracted for 0.1° grid units of latitude and longitude

For the Kozushima Island area, grid number 23 was used.

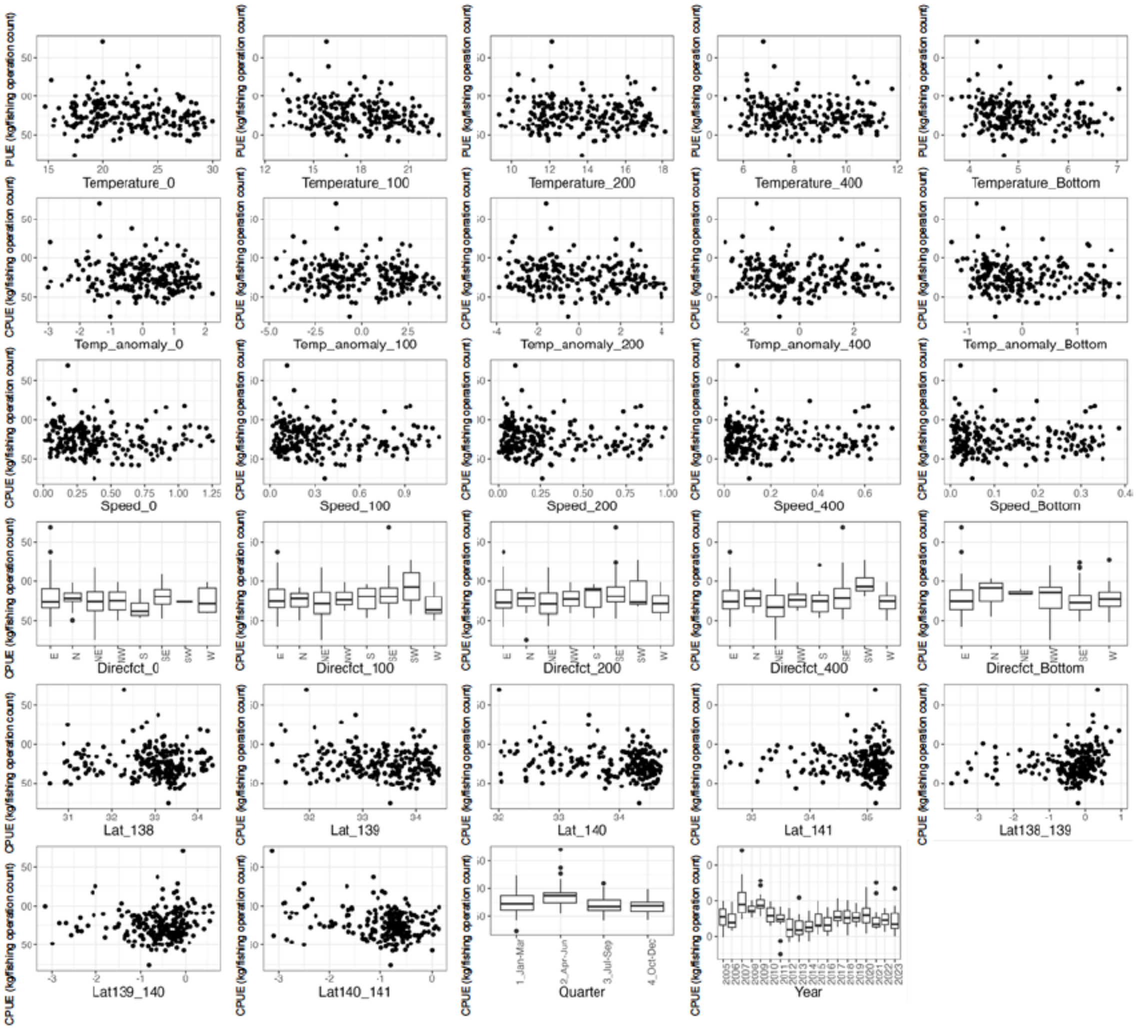

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

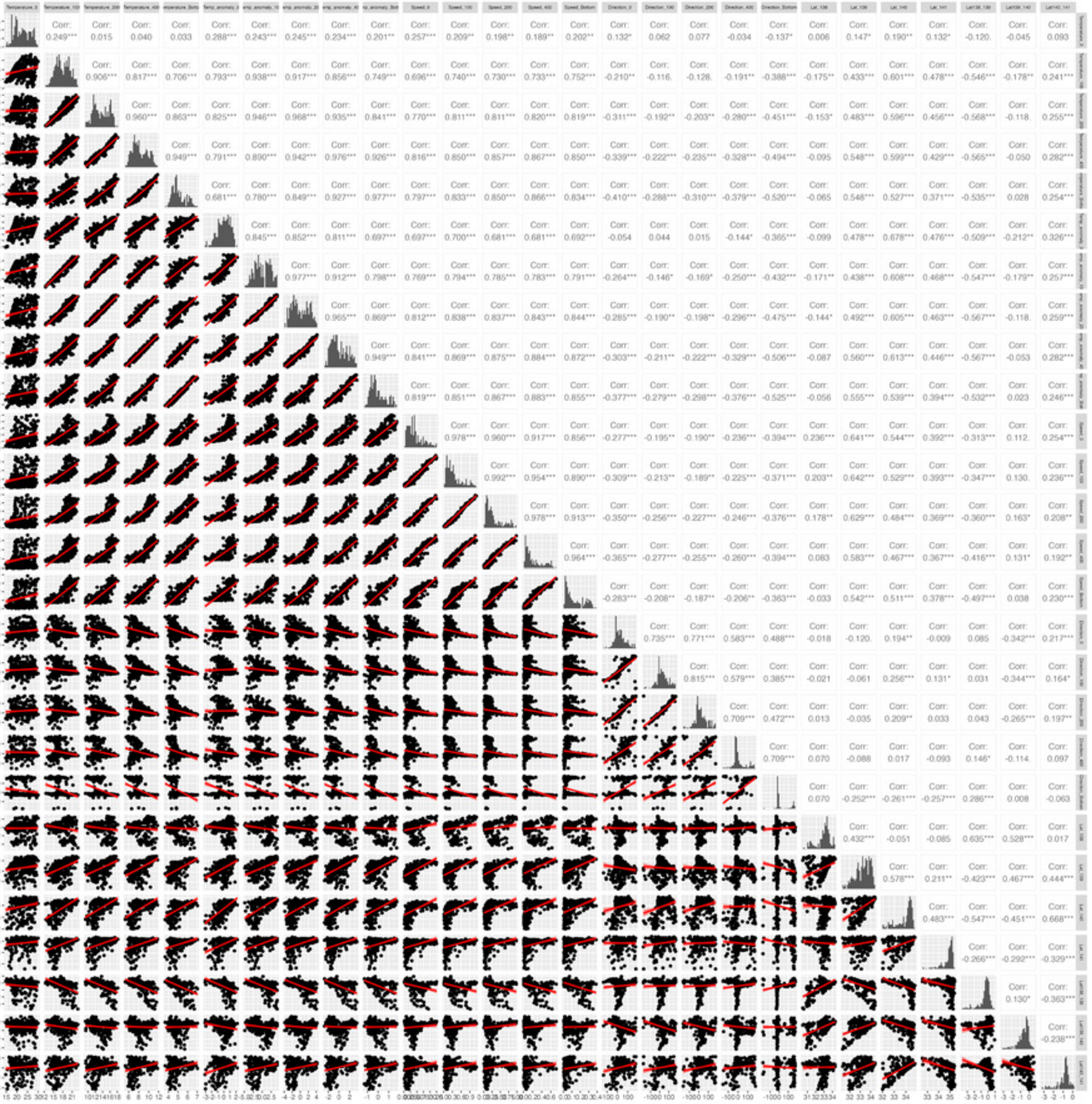

Fig. 3. Correlation between the marine environmental data used in the standardization model

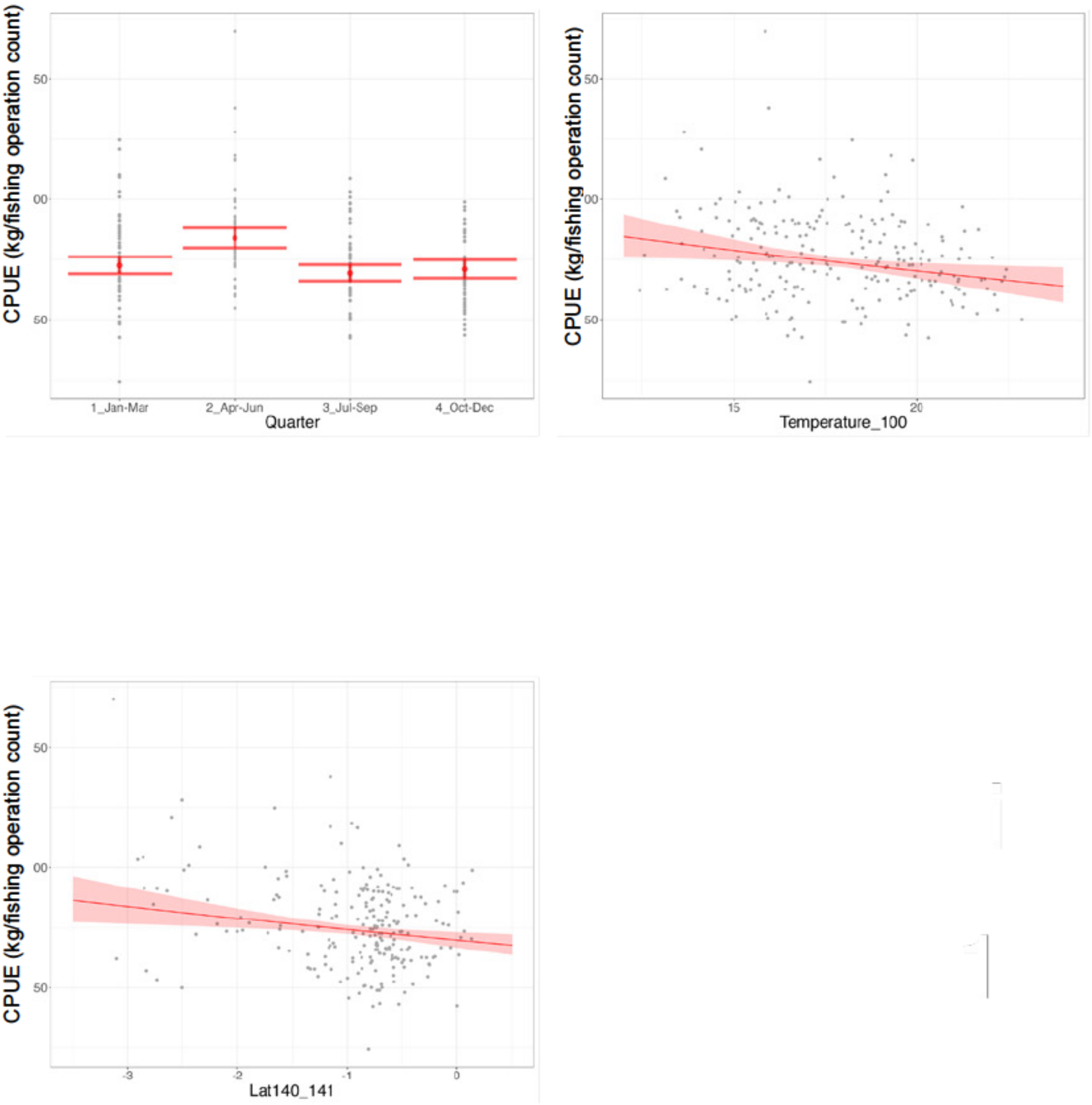

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

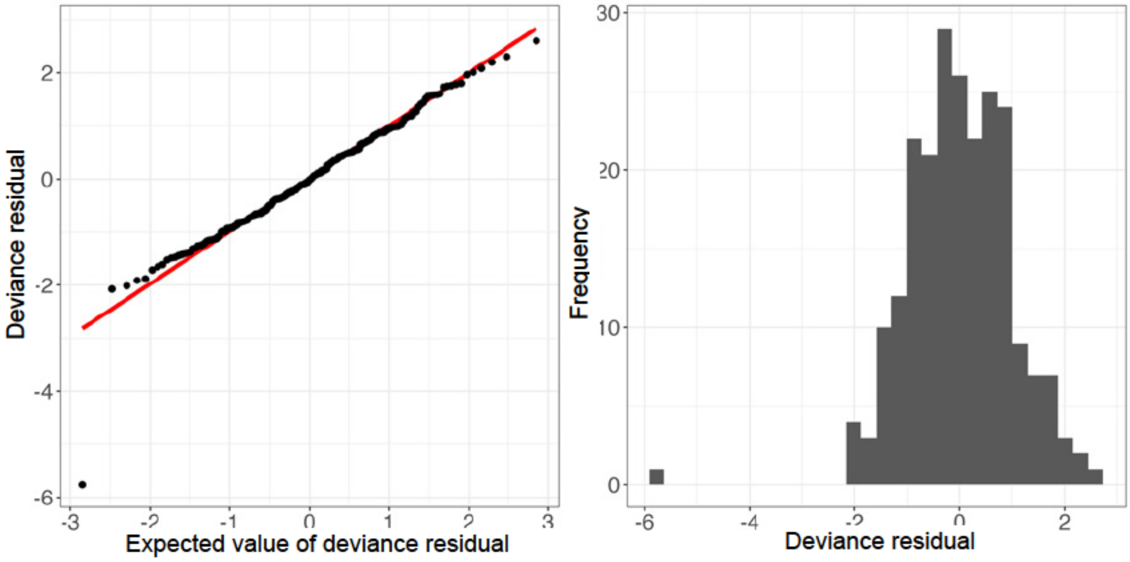

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

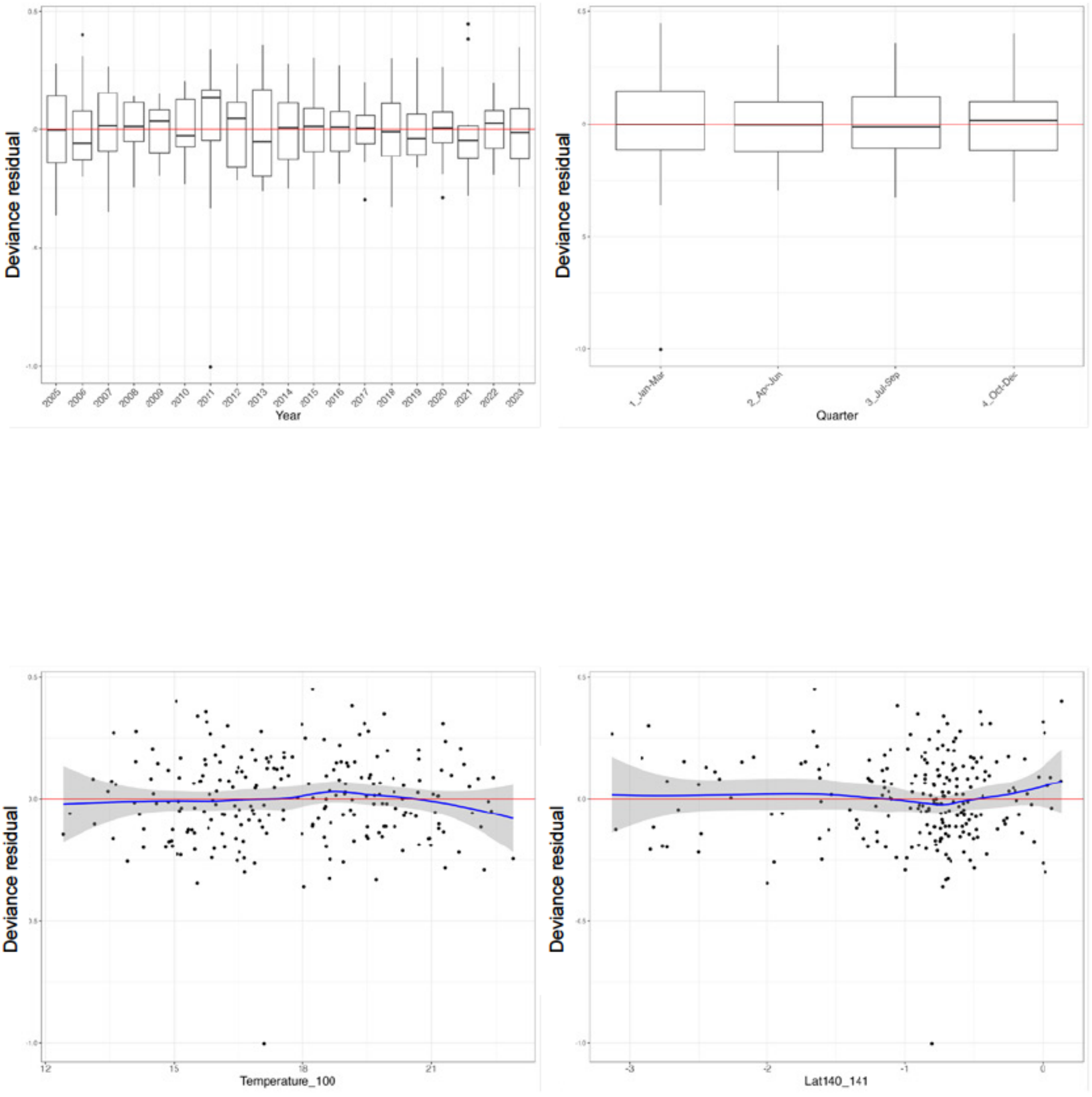

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Temperature_100 and Lat140_141 represent fitted smoothing curves (loess) and their 95% confidence intervals.

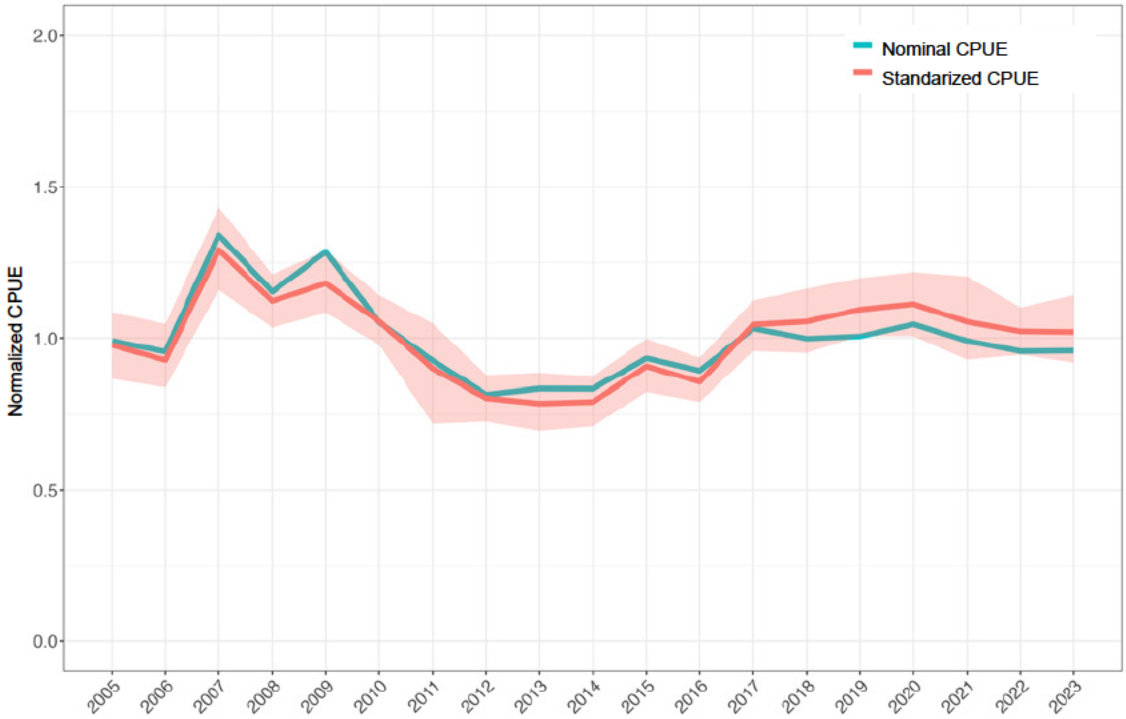

Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Lat140_141 + Quarter + Temperature_100 + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	4.622	0.163	28.327	0.0000	***
Lat140_141	-0.060	0.021	-2.842	0.0049	**
Quarter2_Apr-Jun	0.146	0.035	4.228	0.0000	***
Quarter3_Jul-Sep	-0.044	0.034	-1.273	0.2045	
Quarter4_Oct-Dec	-0.021	0.038	-0.548	0.5846	
Temperature_100	-0.023	0.009	-2.572	0.0108	*
Year2006	-0.053	0.078	-0.673	0.5018	
Year2007	0.279	0.075	3.721	0.0003	***
Year2008	0.139	0.076	1.838	0.0675	.
Year2009	0.189	0.077	2.455	0.0149	*
Year2010	0.077	0.075	1.023	0.3073	
Year2011	-0.083	0.075	-1.105	0.2705	
Year2012	-0.196	0.075	-2.610	0.0097	**
Year2013	-0.218	0.076	-2.863	0.0046	**
Year2014	-0.212	0.075	-2.806	0.0055	**
Year2015	-0.075	0.075	-1.001	0.3180	
Year2016	-0.133	0.075	-1.765	0.0790	.
Year2017	0.067	0.075	0.891	0.3742	
Year2018	0.076	0.077	0.983	0.3269	
Year2019	0.114	0.080	1.413	0.1593	
Year2020	0.130	0.081	1.602	0.1108	
Year2021	0.075	0.081	0.932	0.3523	
Year2022	0.045	0.079	0.572	0.5678	
Year2023	0.043	0.081	0.534	0.5941	

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

	Estimate	Standard Error	z value	Pr(>|z|)

(Dispersion parameter for Gaussian family taken to be 0.03355132)

Null deviance: 13.11 on 227 degrees of freedom

Residual deviance: 6.844 on 204 degrees of freedom

AIC: -102.31

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)
Standardization of CPUE for Splendid Alfonsino (Miyakejima Island Area, Tokyo Metropolis)

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency
Yohei Kawauchi, Aigo Takeshige, Shingo Watari, Shion Takemura, Kazuhiro Aoki, Hitomi Oyaizu

Summary

Data	Catch and number of landings (day･vessel) data by month for vertical longline fishery of Splendid Alfonsino in Miyakejima Island Area, Tokyo Metropolis. Fishing operation location data are not included. Water temperature, direction, and speed of sea currenet in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard's Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day･vessel)
Data availability period	2007-2023
Period used for standardization	2007-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical value as fixed effects) Water temperature, current speed, the latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, the water temperature at the bottom layer, current velocity at 0 m depth layer
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects
Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.

Results of CPUE standardization	Although standardized CPUE tended to remain almost flat after 2007 to around 2012, it increased between 2013 and 2014, and after 2014, it tended to remain almost flat despite some fluctuations. However, it decreased continuously for 3 years from 2021 onward. There were no significant differences between the values of standardized CPUE and nominal CPUE. However, nominal CPUE was higher in 2007 and from 2009 to 2010, while standardized CPUE was significantly higher from 2017 onward.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We used “year”, “season”, ”area”, and “the distance to the Kuroshio axis” (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised fishermanregarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enought. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds and entire habitat of the stock) (Watari et al., 2023). As a result, it was determined that the standardized CPUE of 6 areas among the 7 areas in the four Tokyo and three prefectures considered the influence of environmental factors more thoroughly, and since the model diagnostic results were generally good, it was decided to introduce it as one of the tuning indices for the VPA (Standardized CPUE is still being examined for the Hachijo Island Area). In 2023, to correspond to the “Expansion of standardized CPUE to areas of the ocean where it has not yet been implemented”, one of the topics identified for future consideration during the assessment of this stock, the standardized CPUE was examined using the data from the Miyakejima Island Area of Tokyo Metropolis (Watari et al., 2024). As a result, the model diagnostic results were generally favorable, and changes in the CPUE caused by the influence of environmental factors were corrected. Therefore, it was decided to use the yearly trend derived from this model as one of the tuning indices for the VPA of the Splendid Alfonsino of Pacific Japan.

This fiscal year, as in previous fiscal years, the standardization model for the Miyakejima Island Area of Tokyo Metropolis has been updated with the most recent data for the current fiscal year.

2. Method

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2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Miyakejima Island Area, the latitude of the Kuroshio northern edge at 139°E (Lat_139) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) Calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were used as indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. For the Miyakejima Island Area, grid number 25 in Fig. 1 was selected as fishing grounds for analysis. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Direcfct) after monthrly averaging. For current direction and current speed, the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_400 +
Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_400 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_400 + Direcfct_Bottom +
Lat_139 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, he standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.. The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike's Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plots, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Quarter + Temperature_Bottom + Speed_0

For the Miyakejima Island Area, as a result of the model selection process using an exhaustive search based on AIC, 11 models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. The models of the minimum AIC+2 range suggested that, in addition to the explanatory variables selected in the best model, many models also included indices of the Kuroshio intrusion and current velocity of the bottom layer, indicating a tendency toward selecting explanatory variables associated with the influence of the Kuroshio and flow within the fishing grounds. The CPUE responses (Fig. 4) to the selected explanatory variables in the best model also detected changes in the CPUE influenced by the current velocity within the fishing grounds and water temperature.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. Although standardized CPUE tended to remain almost flat after 2007 to around 2012, it increased between 2013 and 2014, and after 2014, it tended to remain almost flat despite some fluctuations. However, it decreased continuously for 3 years from 2021 onward. There were no significant differences between the values of standardized CPUE and nominal CPUE. However, nominal CPUE was higher in 2007 and from 2009 to 2010, while standardized CPUE was significantly higher from 2017 onward.

3.2 Comparison with the Previous Fiscal Year’s Results

The explanatory variables selected for this fiscal year’s best model were the same as those of the previous fiscal year, and there were no significant differences from the previous year in the standardized CPUE trends derived from the best model.

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Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

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Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction					Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Season	Year	df	logLik	AIC	delta
	0	100	200	400	Bottom	139°E	138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom						
4.91					+				-0.06	-0.26									-0.32	+	+	29	-19.6	97.1	0.0
5.09					+					-0.31									-0.35	+	+	28	-20.8	97.7	0.5
4.96					+		-0.04		-0.07	-0.26									-0.34	+	+	30	-18.8	97.7	0.5
6.94					+	-0.06				-0.25									-0.33	+	+	29	-20.1	98.2	1.1
6.96					+	-0.06	-0.05		-0.06	-0.21									-0.34	+	+	31	-18.2	98.4	1.3
4.92					+			-0.03	-0.06	-0.27									-0.33	+	+	30	-19.2	98.5	1.3
7.86					+	-0.08	-0.05			-0.23									-0.36	+	+	30	-19.3	98.5	1.4
6.05					+	-0.03			-0.05	-0.23									-0.31	+	+	30	-19.3	98.7	1.5
4.98					+		-0.04	-0.04	-0.07	-0.27									-0.35	+	+	31	-18.4	98.8	1.6
5.15					+		-0.03			-0.32									-0.37	+	+	29	-20.5	99.1	2.0
4.91										-0.22									-0.33	+	+	23	-26.6	99.1	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2007	0.92	0.84	0.71	0.96	0.08
2008	0.99	0.97	0.87	1.07	0.05
2009	0.93	0.81	0.66	1.01	0.11
2010	1.03	0.91	0.60	1.30	0.19
2011	0.77	0.80	0.69	0.93	0.07
2012	0.70	0.69	0.61	0.80	0.07
2013	1.03	0.97	0.80	1.16	0.10
2014	1.20	1.23	1.06	1.46	0.08
2015	1.06	0.99	0.83	1.17	0.09
2016	0.96	0.96	0.85	1.06	0.05
2017	1.30	1.33	1.13	1.53	0.08
2018	1.20	1.24	0.98	1.45	0.10
2019	1.04	1.11	1.01	1.22	0.05
2020	1.17	1.22	1.02	1.44	0.09
2021	1.08	1.15	1.01	1.27	0.06
2022	0.83	0.93	0.76	1.10	0.09
2023	0.78	0.83	0.70	0.97	0.08

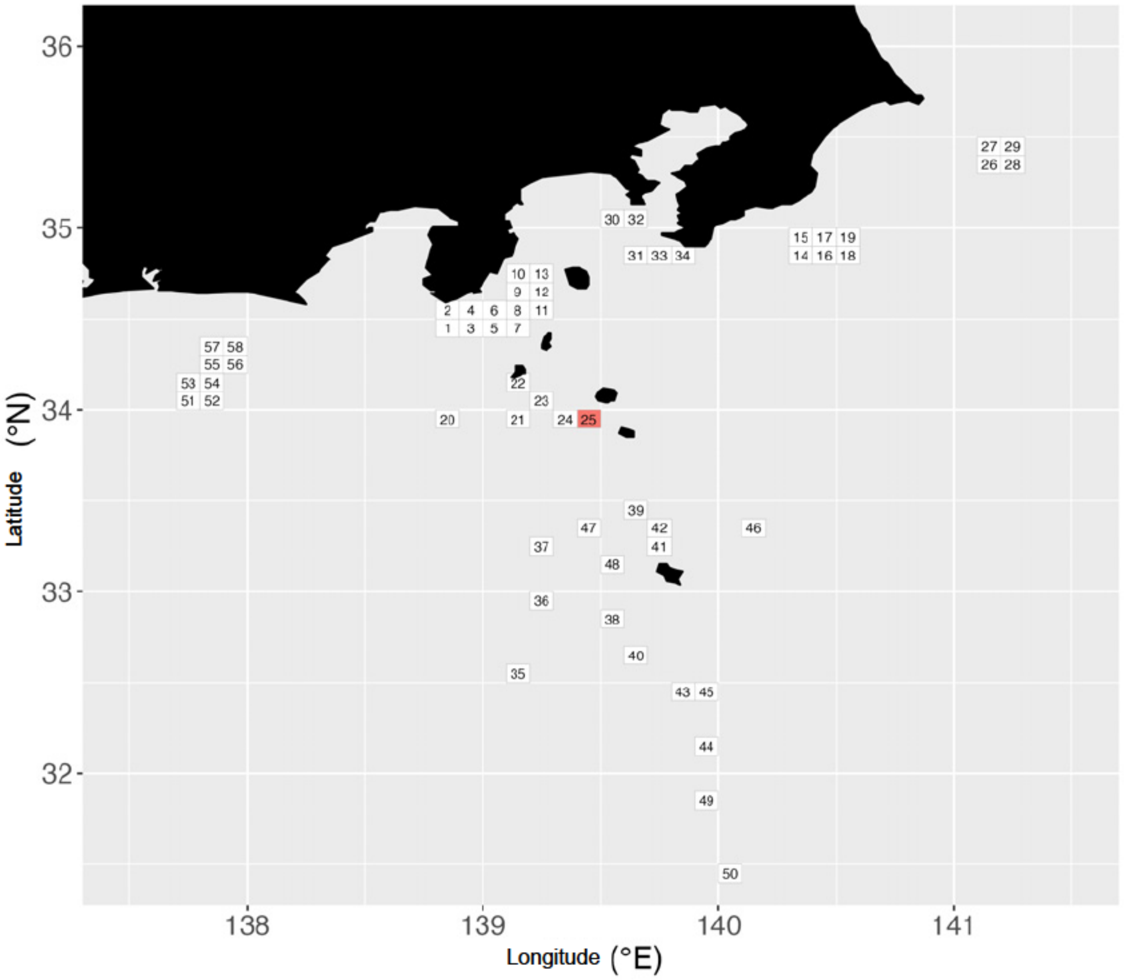

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values - Data extracted for 0.1° grid units of latitude and longitude

For the Miyakejima Island area, grid number 25 was used.

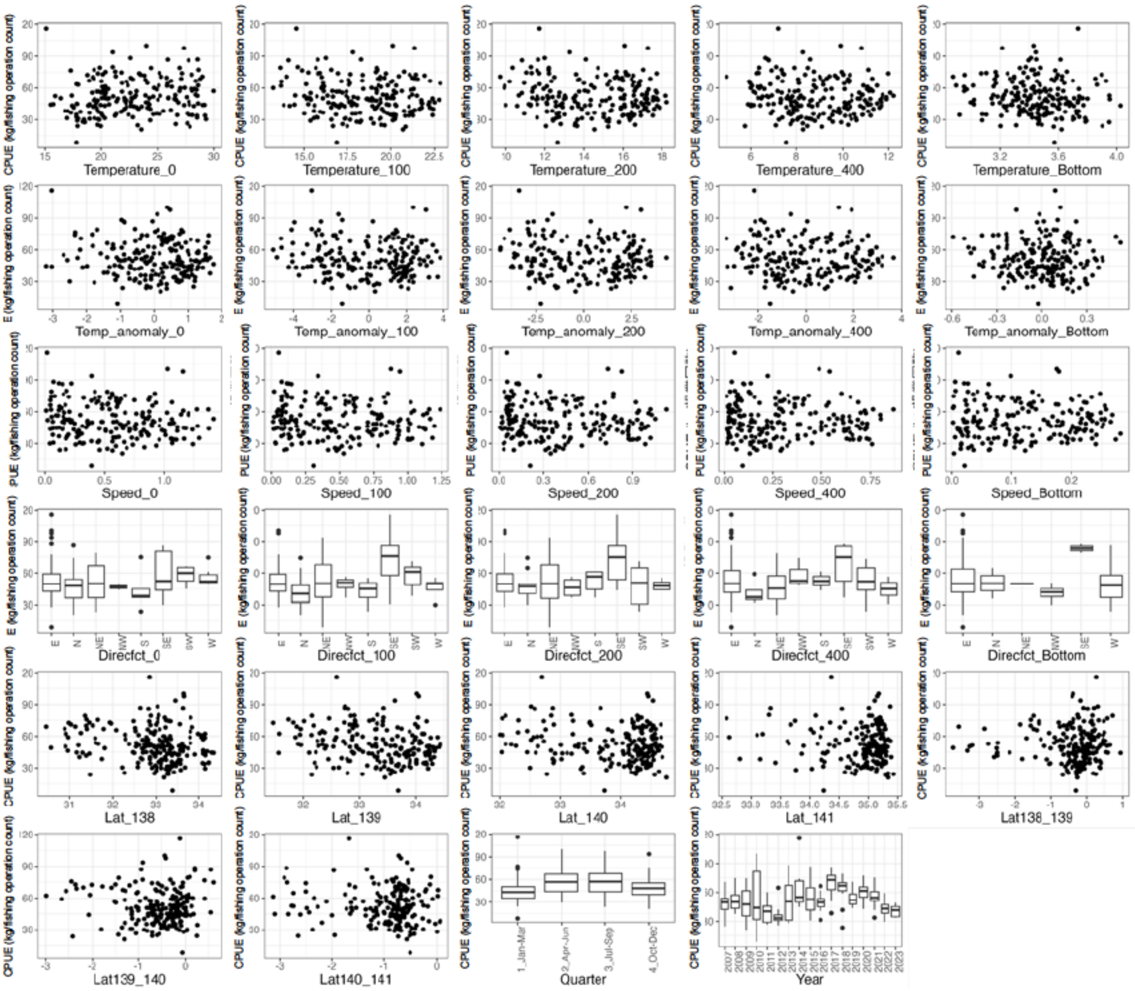

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

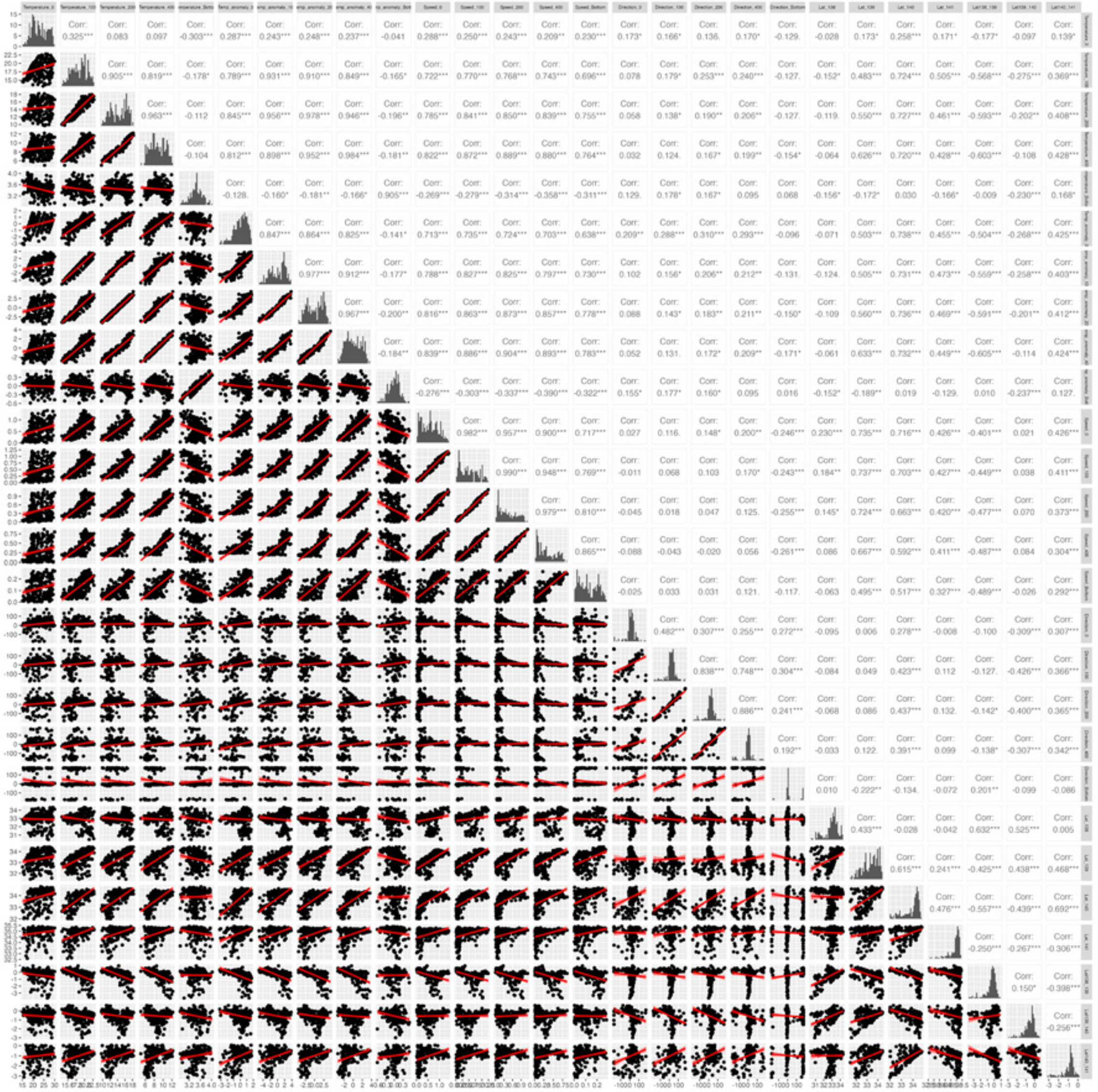

Fig. 3. Correlation between the marine environmental data used in the standardization model

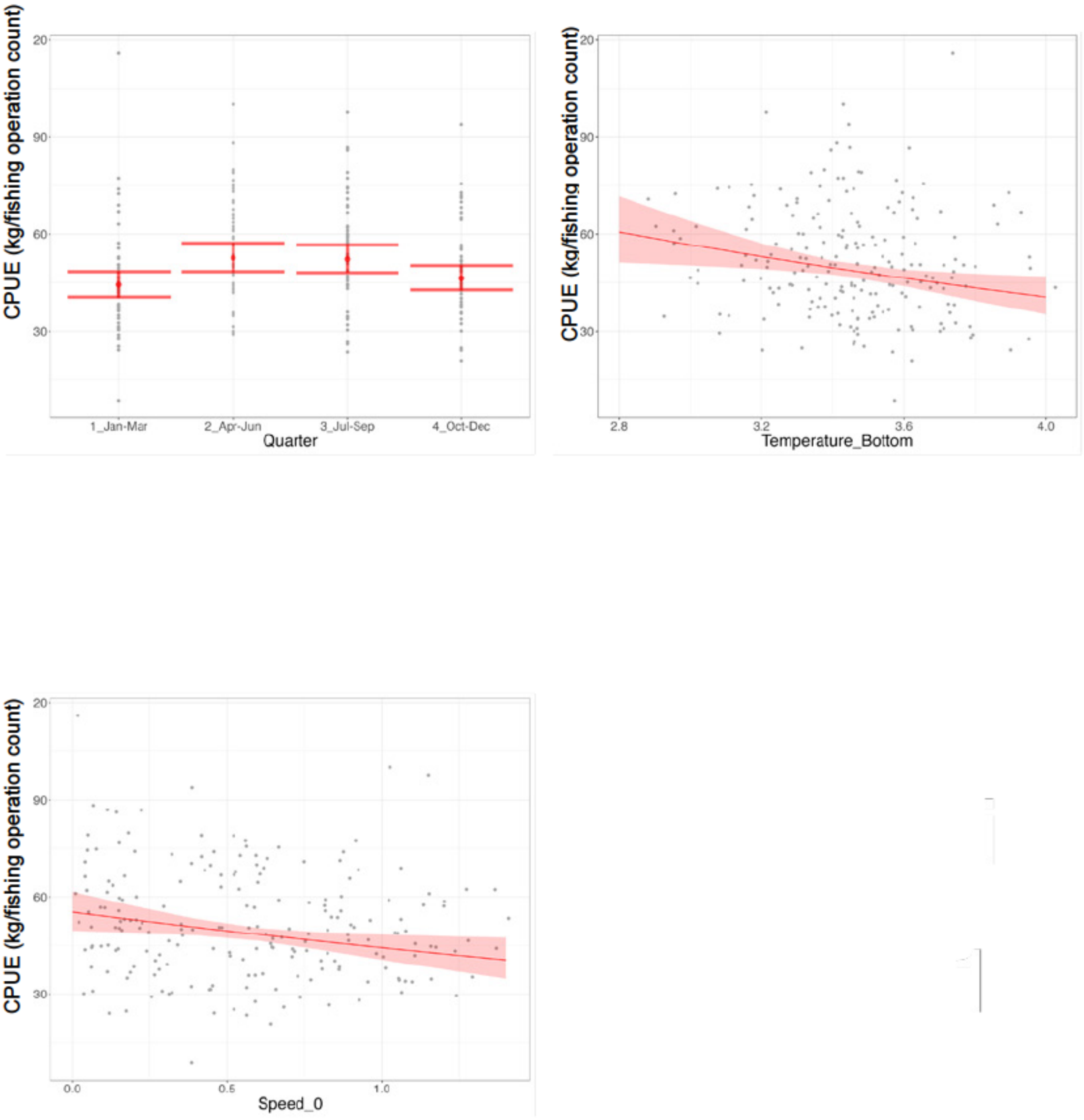

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

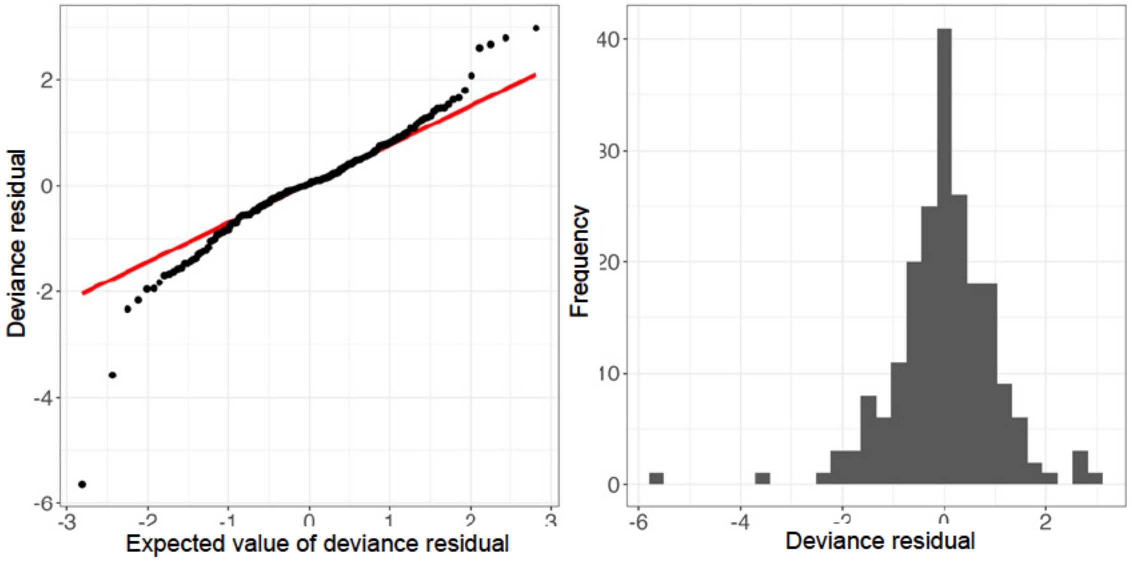

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

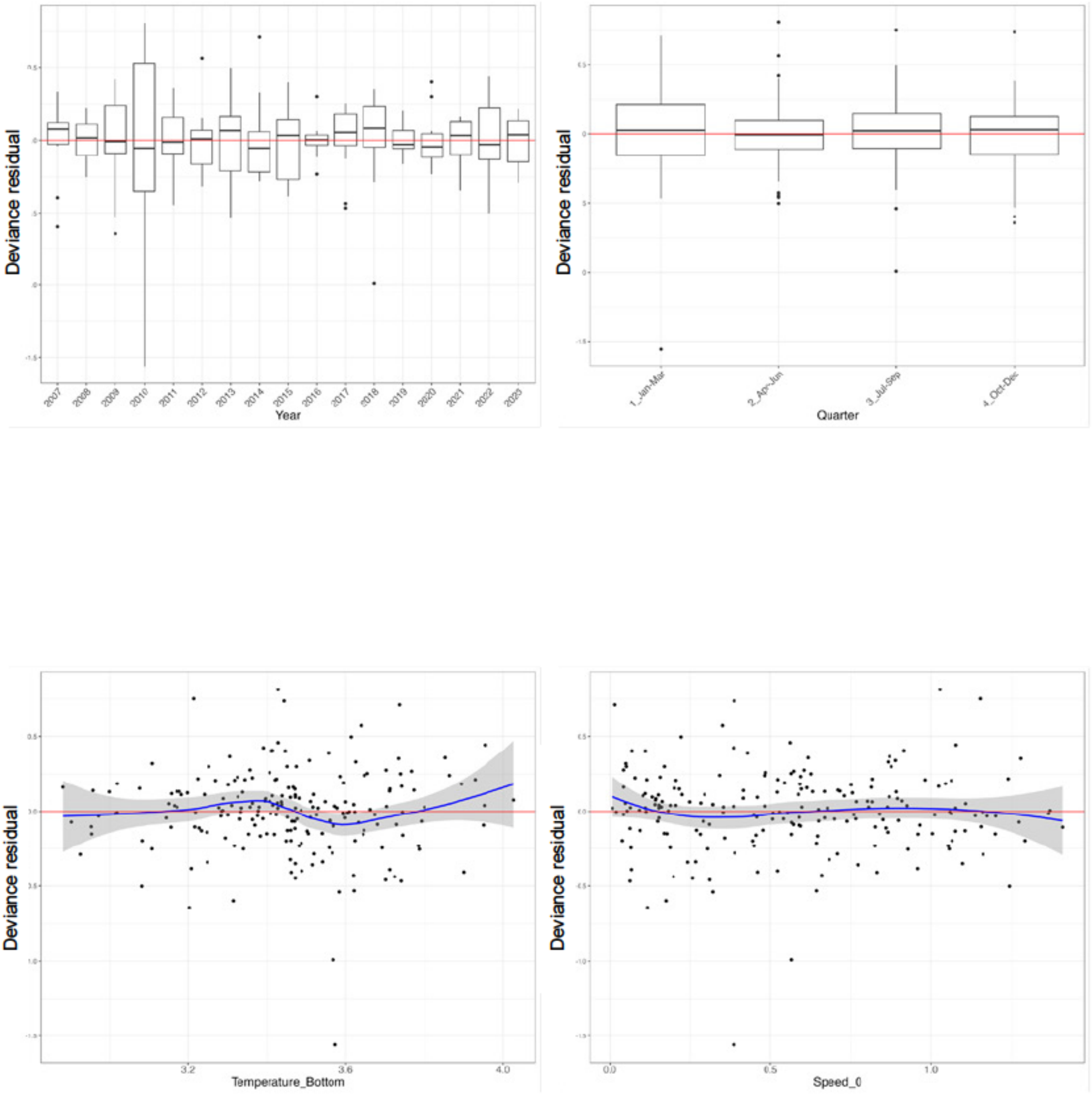

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Temperature_Bottom and Speed_0 represent fitted smoothing curves (loess) and their 95% confidence intervals.

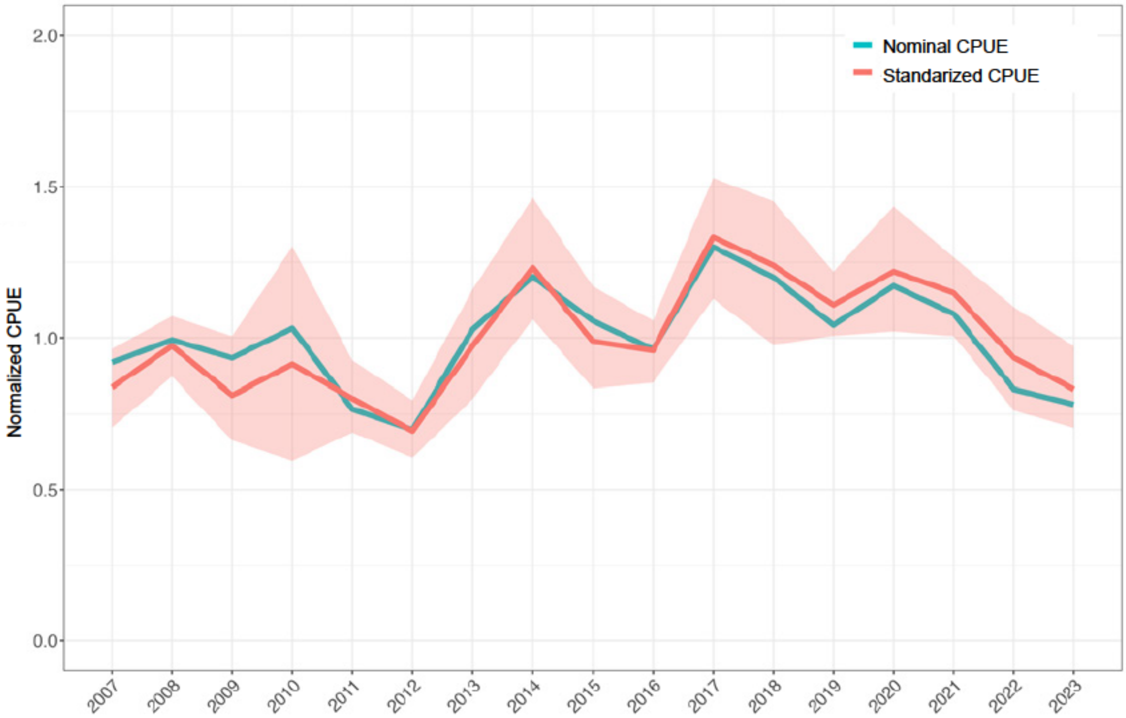

Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Quarter + Speed_0 + Temperature_Bottom + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	4.910	0.450	10.919	0.0000	***
Quarter2_Apr-Jun	0.172	0.065	2.655	0.0086	**
Quarter3_Jul-Sep	0.164	0.064	2.588	0.0104	*
Quarter4_Oct-Dec	0.045	0.062	0.720	0.4722	
Speed_0	-0.221	0.091	-2.423	0.0164	*
Temperature_Bottom	-0.335	0.127	-2.640	0.0090	**
Year2008	0.152	0.121	1.251	0.2124	
Year2009	-0.031	0.120	-0.260	0.7951	
Year2010	0.087	0.124	0.702	0.4833	
Year2011	-0.044	0.124	-0.351	0.7257	
Year2012	-0.186	0.121	-1.539	0.1254	
Year2013	0.152	0.122	1.241	0.2163	
Year2014	0.387	0.124	3.129	0.0020	**
Year2015	0.166	0.123	1.352	0.1780	
Year2016	0.136	0.124	1.097	0.2740	
Year2017	0.466	0.126	3.707	0.0003	***
Year2018	0.393	0.124	3.171	0.0018	**
Year2019	0.282	0.127	2.217	0.0278	*
Year2020	0.377	0.135	2.796	0.0057	**
Year2021	0.317	0.128	2.484	0.0139	*
Year2022	0.111	0.134	0.822	0.4119	
Year2023	-0.007	0.136	-0.055	0.9563	

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 0.08515227)

	Estimate	Standard Error	z value	Pr(>|z|)

Null deviance: 24.23 on 203 degrees of freedom

Residual deviance: 15.5 on 182 degrees of freedom

AIC: 99.13

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024) Standardization of CPUE for Splendid Alfonsino (Hachijojima Island Area, Tokyo Metropolis)

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency
Yohei Kawauchi, Aigo Takeshige, Shingo Watari, Shion Takemura, Kazuhiro Aoki, Hitomi Oyaizu

Summary

Data	Catch and number of landings (day･vessel) data by month for vertical longline fishery of Splendid Alfonsino in Hachijojima Island Area, Tokyo Metropolis. Fishing operation location data are not included. Water temperature, direction, and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard's Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day･vessel)
Data availability period	2006-2023
Period used for standardization	2006-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical value as fixed effects) Water temperature, current speed, the latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, current direction at 100 m layer, latitudinal difference of the northern edge of Kuroshio between longitudes 138°E and 139°E
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects

Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.
Results of CPUE standardization	Of the models that include year effects, the standardized CPUE calculated by the best model selected by the above criterion increased from 2009 to 2010. Thereafter, the trend remained flat, with small increases and decreases. However, after 2022, standardized CPUE increased for 2 consecutive years, reaching its highest value during the analysis period in 2023. The long-term trend of nominal CPUE differed from that of standardized CPUE; it remained almost flat despite some fluctuations until 2018 before showing a slight decrease in 2019. Although there has been a slight increasing trend since 2020, as of 2023, it has not yet reached the high level of standardized CPUE. The standardized CPUE was higher in 2010, 2011, and from 2018 onward. However, it was determined that an appropriate standardized CPUE had not been obtained at this time due to issues with model selection and the possibility that the model did not adequately account for differences in the marine environment within the fishing grounds.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We used “year”, “season”, “area” and “the distance to the Kuroshio axis” (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from key points documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari & Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised by fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds and entire habitat of the stock) (Watari et al., 2023). Model selection was conducted using data from the Hachijojima Island Area, Tokyo Metropolis. As year effects were not included in the top models based on the Akaike Information Criterion (AIC), the best model was chosen from those that included year effects. The annual trends obtained from the best model corrected for lower CPUE due to the effects of water temperature and current direction in the fishing grounds, and the model diagnostic results were generally favorable. However, after consulting organizations participating in the stock assessment, it was decided not to introduce standardized CPUE for the Hachijojima Island Area as one of the tuning indices for the VPA this fiscal year. This decision was based on the fact that, as mentioned above, the top models based on AIC did not include year effects, and appropriate modeling may not be possible due to current limitations in data resolution.

This fiscal year, the examination was continued by adding the latest year’s data to the dataset from the previous fiscal year. However, as in the previous fiscal year, the top models based on AIC did not include year effects, and the issues were not considered to be adequately resolved. Therefore, it was determined that continuing to incorporate standardized CPUE into the biomass calculation would be difficult. Details of the model and standardized CPUEs are described below for reference.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Hachijojima Island area of Tokyo Metropolis, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day･vessel) and does not include fishing operation location data. The standardization period was 2006-2023, and all records were used for the analysis.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were introduced used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Hachijojima Island area, the latitude of the Kuroshio northern edge at 139°E (Lat_139) was used as an explanatory variable to consider the position of the Kuroshio current in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) was calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were used as indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. For the Hachijojima Island area, grid number 40 in Fig. 1 was selected as fishing grounds for analysis. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Direcfct) after monthly averaging. For current direction and current speed, the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.

Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.

Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_400 +
Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_400 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_400 + Direcfct_Bottom +
Lat_139 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.. The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike's Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plot, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Model selection was conducted based on the above selection criteria. However, since models within the minimum AIC+2 range did not include year effects (Table 1), the selection was restricted to models that included year effects, and the following was chosen as the best model in accordance with the criteria (Table 2).

log(CPUE) ~ Year + Quarter + Direcfct_100 + Lat138_139

For the Hachijojima Island area, as a result of the model selection process using an exhaustive search based on AIC, 17 models were within the minimum AIC+2 range among the candidate models that included year effects after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. Upon reviewing other candidate models, the trend that explanatory variables related to the influence of the Kuroshio intrusion, current velocities within the fishing grounds and water temperature were more likely to be selected for the best model was observed. The CPUE responses to each of the selected explanatory variables in the best model (Fig. 4) also detected changes in the CPUE caused by the current direction or Kuroshio intrusion.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch volumes and net counts are presented in Fig. 7 and Table 3. The standardized CPUE increased from 2009 to 2010. Thereafter, the trend remained flat up to 2021, with small increases and decreases. However, after 2022, standardized CPUE increased for 2 consecutive years, reaching its highest value during the analysis period in 2023. The long-term trend of nominal CPUE differed from that of standardized CPUE; it remained almost flat despite some fluctuations until 2018 before showing a slight decrease in 2019. Although there has been a slight increasing trend since 2020, as of 2023, it has not yet reached the high level of standardized CPUE. Standardized CPUE was higher in 2010, 2011, and from 2018 onward.

As described above, the top models based on AIC in the Hachijojima Island Area did not include year effects, so the best model was selected from those that did. Although the marine environmental data of grid 40 in Fig. 1 was used as representative of the fishing grounds in the Hachijojima Island Area, the fishing grounds in this area cover a wide range, spanning grids 35 to 50. This fiscal year, calculations were also examined using weighted marine environmental data as explanatory variables based on annual changes in the distribution of fishing effort per grid obtained through interviews with fishermen through organizations participating in the stock assessment. However, similarly, none of the top models based on AIC included year effects. The standardized CPUE estimated this fiscal year was determined to be inappropriate for use in the biomass calculation for the Splendid Alfonsino of Pacific Japan, as it was considered that differences in the marine environment within the fishing grounds, which are broader than those in other sea areas, may not have been adequately accounted for. It is essential to carefully examine past information and standardize CPUE with the aim of further improving stock assessments, even when the available information is limited.

3.2 Comparison with the Previous Fiscal Year's Results

This fiscal year, the explanatory variables for the best model selected from the model candidates that included year effects current direction at the 100 m depth instead of the current direction at the 0 m depth and water temperature at the 400 m depth, which were included in the previous fiscal year. On the other hand, while the latitudinal difference of the Kuroshio Current's northern edge between 138°E and 139°E was not included in the previous fiscal year, it has been included this year. However, no significant change in the trend of standardized CPUE was observed.

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Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

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Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II.

Depth	Flow direction					Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Sea-son	Year	df	logLik	AIC	delta
	0	100	200	400	Bottom	139°E	138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom						
5.04																		-0.02		+		6	-123.6	259.1	0.0
5.22																	-0.03			+		6	-123.7	259.4	0.3
5.42																-0.04				+		6	-124.0	259.9	0.8
5.00							0.03											-0.02		+		7	-123.2	260.5	1.3
5.54													0.31			-0.05				+		7	-123.2	260.5	1.4
5.51	+															-0.04				+		13	-117.3	260.5	1.4
5.46												0.18				-0.04				+		7	-123.3	260.5	1.4
7.71						-0.09														+		6	-124.3	260.5	1.4
5.15							0.04										-0.02			+		7	-123.3	260.6	1.5
4.98																			-0.04	+		6	-124.4	260.7	1.6
5.23													0.20				-0.03			+		7	-123.4	260.8	1.6
5.31							0.04									-0.03				+		7	-123.4	260.8	1.7
5.25														0.47			-0.03			+		7	-123.4	260.8	1.7
5.03														0.33				-0.03		+		7	-123.4	260.8	1.7
5.41											0.13					-0.04				+		7	-123.4	260.8	1.7
6.91						-0.05										-0.02				+		7	-123.5	261.0	1.8
5.19												0.10					-0.03			+		7	-123.5	261.0	1.8
4.80	+						0.09													+		13	-117.5	261.0	1.8
4.98									-0.02									-0.02		+		7	-123.5	261.0	1.9
5.03													0.07					-0.03		+		7	-123.5	261.0	1.9
5.04								0.01										-0.02		+		7	-123.6	261.1	2.0
5.03												0.02						-0.02		+		7	-123.6	261.1	2.0
5.05										-0.02								-0.03		+		7	-123.6	261.1	2.0
5.35						-0.01												-0.02		+		7	-123.6	261.1	2.0
4.75		+					0.09													+		13	-117.6	261.1	2.0
5.37										0.10						-0.04				+		7	-123.6	261.1	2.0
5.04											0.00							-0.02		+		7	-123.6	261.1	2.0

Table 2. Model selection results: Displaying models within the minimum AIC+2 range that includes yearly effects, excluding models containing multiple-depth layers of explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction					Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Sea-son	Year	df	logLik	AIC	delta
	0	100	200	400	Bottom	139°E	138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom						
5.44		+					0.11									-0.04				+	+	31	-102.9	267.9	8.7
5.53		+					0.11					0.21				-0.05				+	+	32	-102.3	268.7	9.5
5.02		+					0.11											-0.03		+	+	31	-103.4	268.8	9.6
5.41		+					0.11			0.14						-0.04				+	+	32	-102.4	268.8	9.7
5.47		+					0.11				0.16					-0.04				+	+	32	-102.4	268.8	9.7
5.57		+					0.11						0.35			-0.05				+	+	32	-102.4	268.8	9.7
5.62	+						0.10									-0.05				+	+	31	-103.4	268.9	9.7
5.15		+					0.11										-0.03			+	+	31	-103.6	269.1	10.0
5.71	+						0.09					0.23				-0.06				+	+	32	-102.7	269.4	10.3
4.66		+					0.16													+	+	30	-104.8	269.5	10.4
5.75	+						0.10						0.39			-0.06				+	+	32	-102.8	269.6	10.4
5.52		+					0.12		0.02							-0.04				+	+	32	-102.9	269.7	10.6
5.65	+						0.09				0.17					-0.05				+	+	32	-102.9	269.7	10.6
5.13	+						0.09											-0.03		+	+	31	-103.9	269.8	10.6
5.40		+					0.12	0.02								-0.04				+	+	32	-102.9	269.8	10.7
5.80		+				-0.01	0.11									-0.04				+	+	32	-102.9	269.9	10.7
5.45		+					0.11							0.07		-0.04				+	+	32	-102.9	269.9	10.7

Table 3. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2006	0.88	0.86	0.62	1.08	0.14
2007	1.00	0.90	0.71	1.10	0.11
2008	0.96	0.70	0.34	1.14	0.32
2009	1.16	0.95	0.72	1.25	0.15
2010	1.03	1.11	0.86	1.43	0.13
2011	1.07	1.11	0.93	1.28	0.08
2012	1.00	0.99	0.84	1.12	0.07
2013	1.26	1.03	0.73	1.39	0.16
2014	1.03	1.00	0.86	1.15	0.07
2015	0.93	0.85	0.69	1.02	0.10
2016	0.97	0.89	0.73	1.05	0.09
2017	1.02	0.92	0.73	1.10	0.11
2018	1.06	1.11	0.92	1.34	0.10
2019	0.78	0.99	0.78	1.32	0.14
2020	0.91	1.01	0.85	1.28	0.11
2021	0.85	0.92	0.74	1.18	0.12
2022	0.93	1.13	0.91	1.46	0.13
2023	1.16	1.53	1.17	2.21	0.18

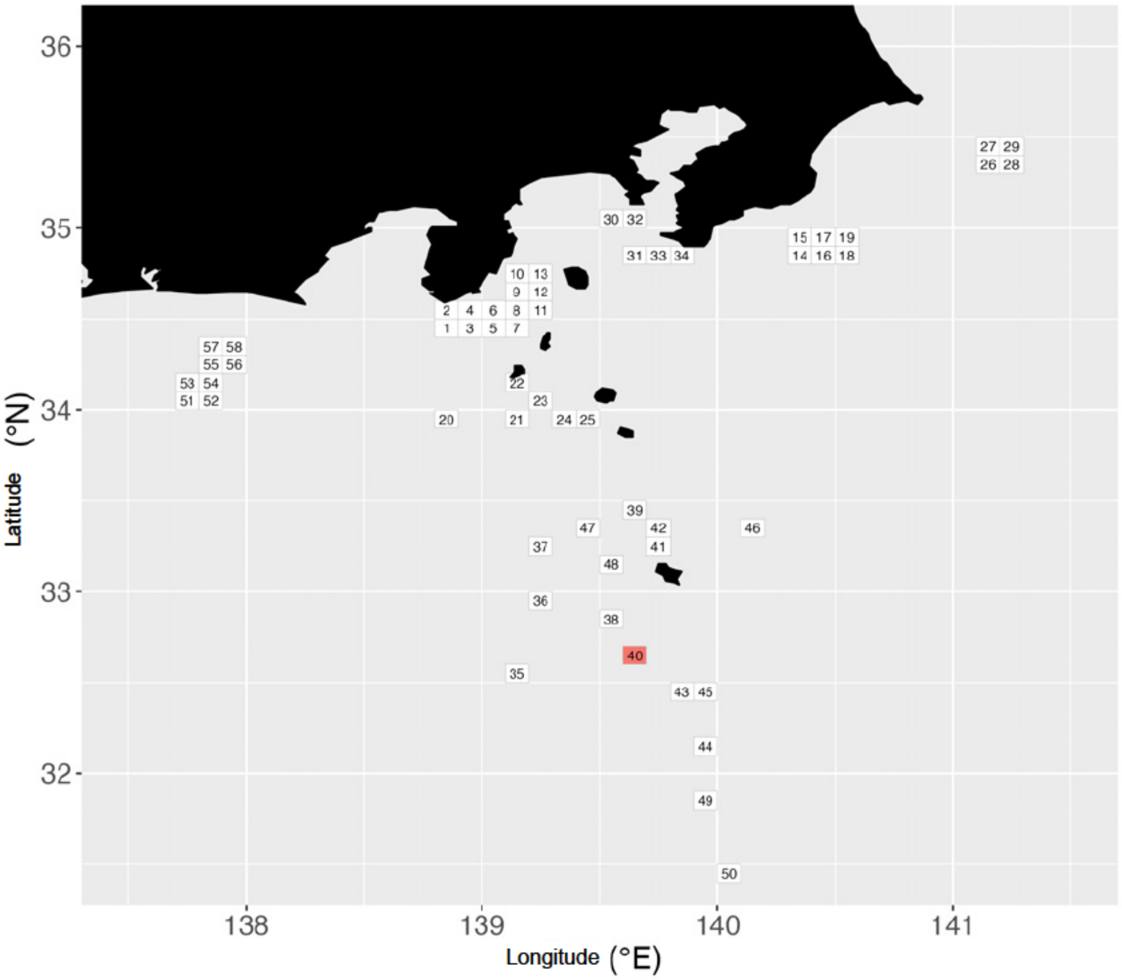

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values - Data extracted for 0.1° grid units of latitude and longitude

For the Hachijojima Island area, grid number 40 was used.

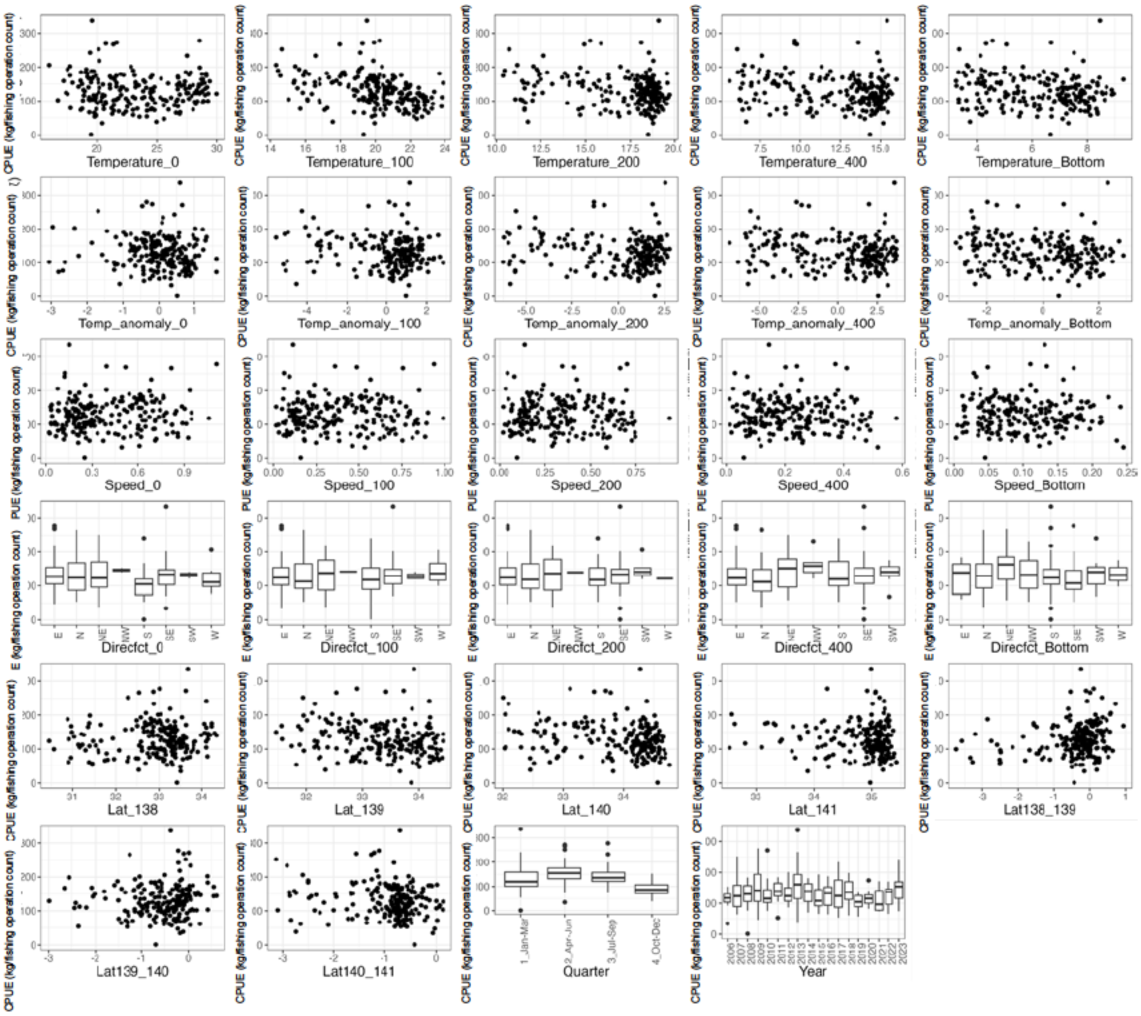

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

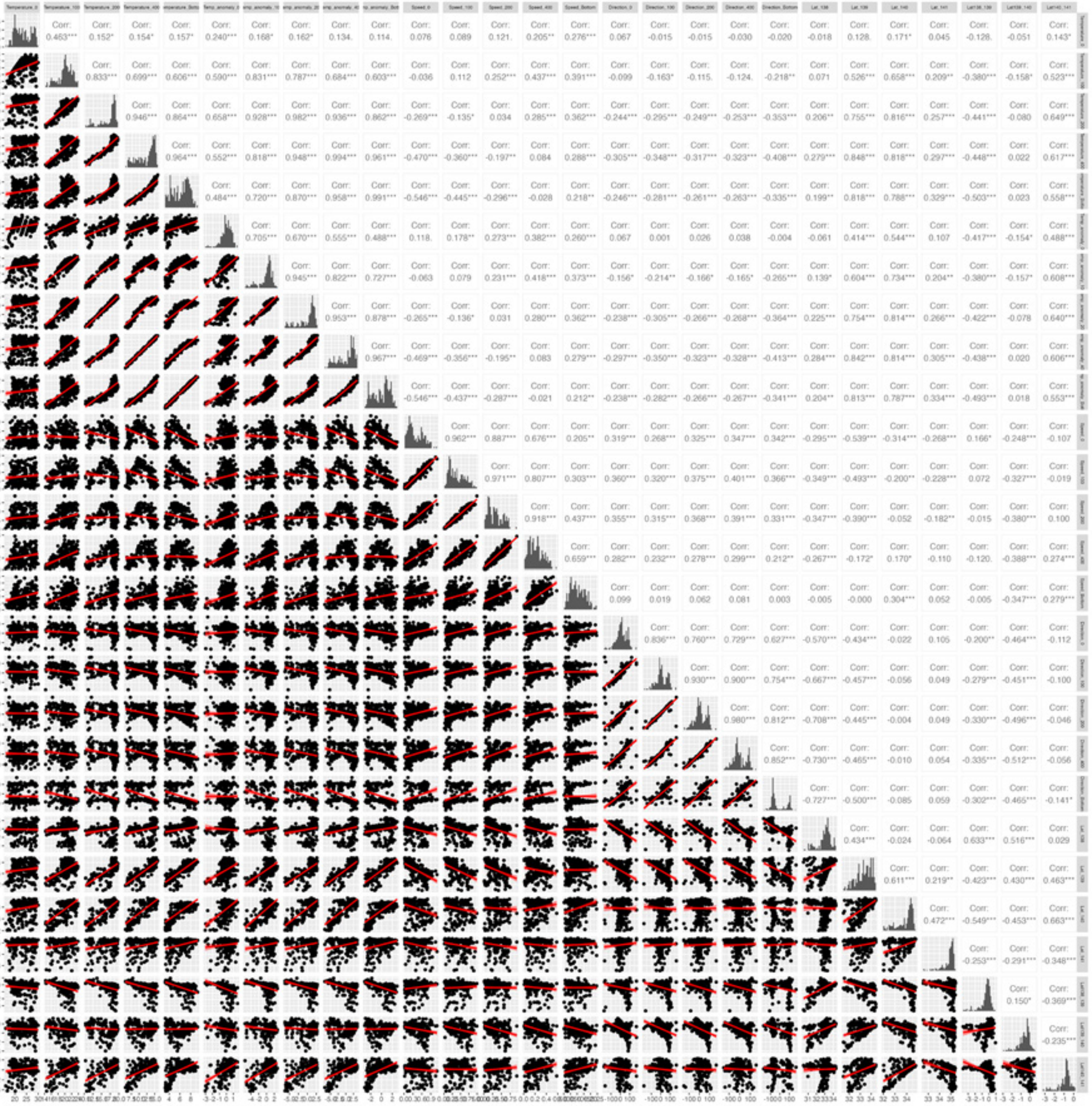

Fig. 3. Correlation between the marine environmental data used in the standardization model

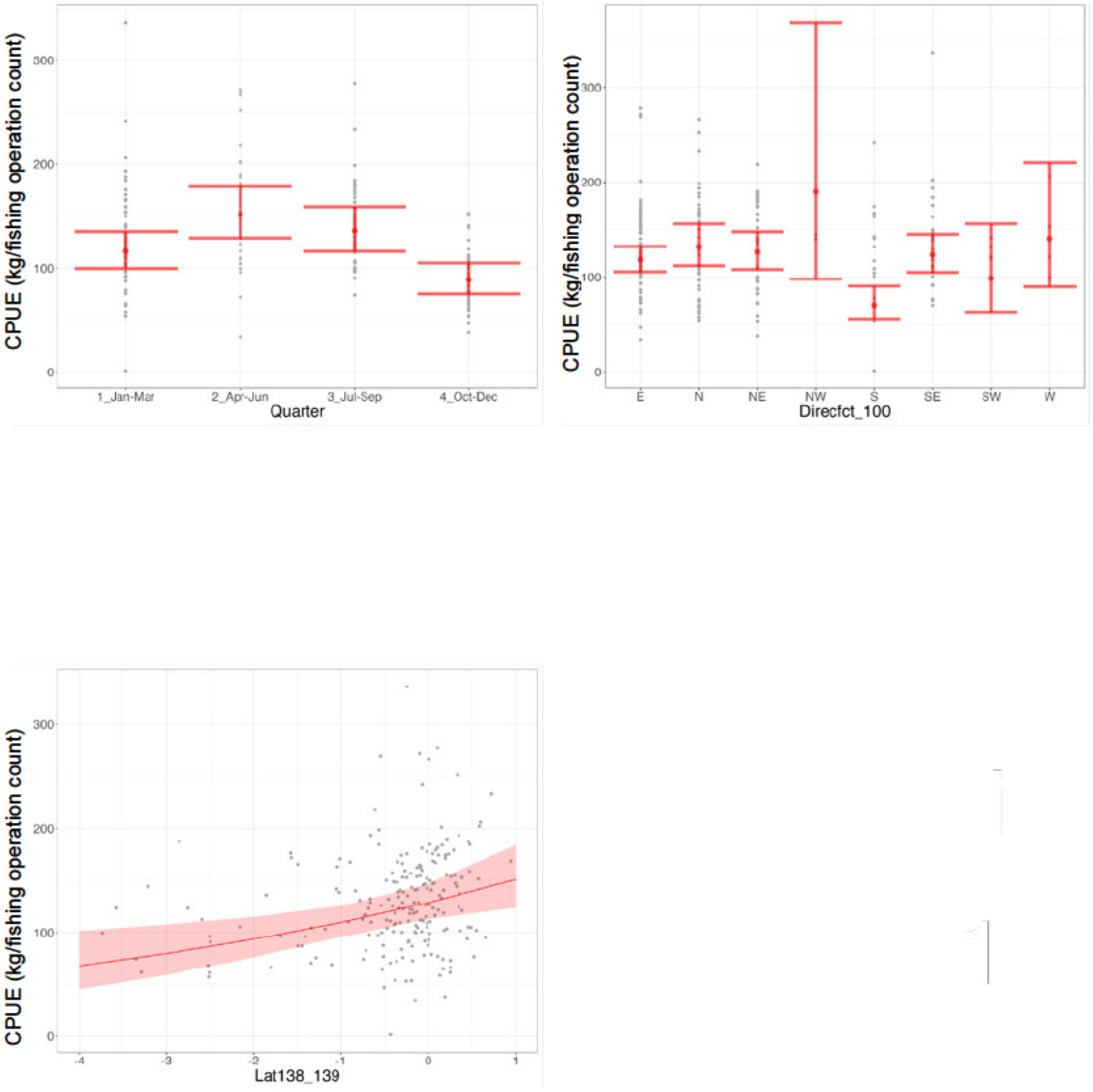

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

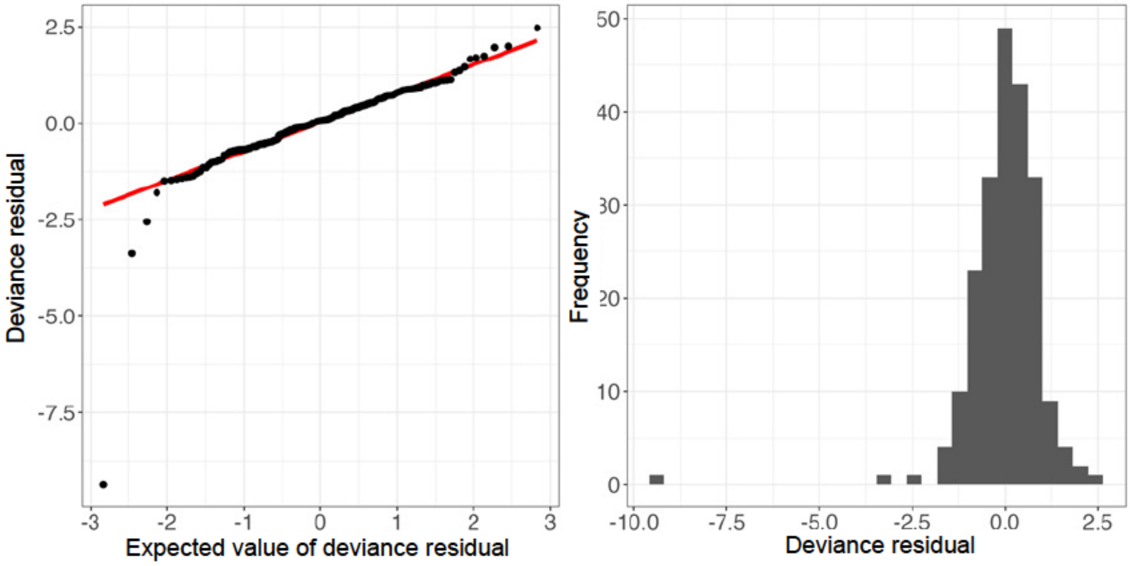

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

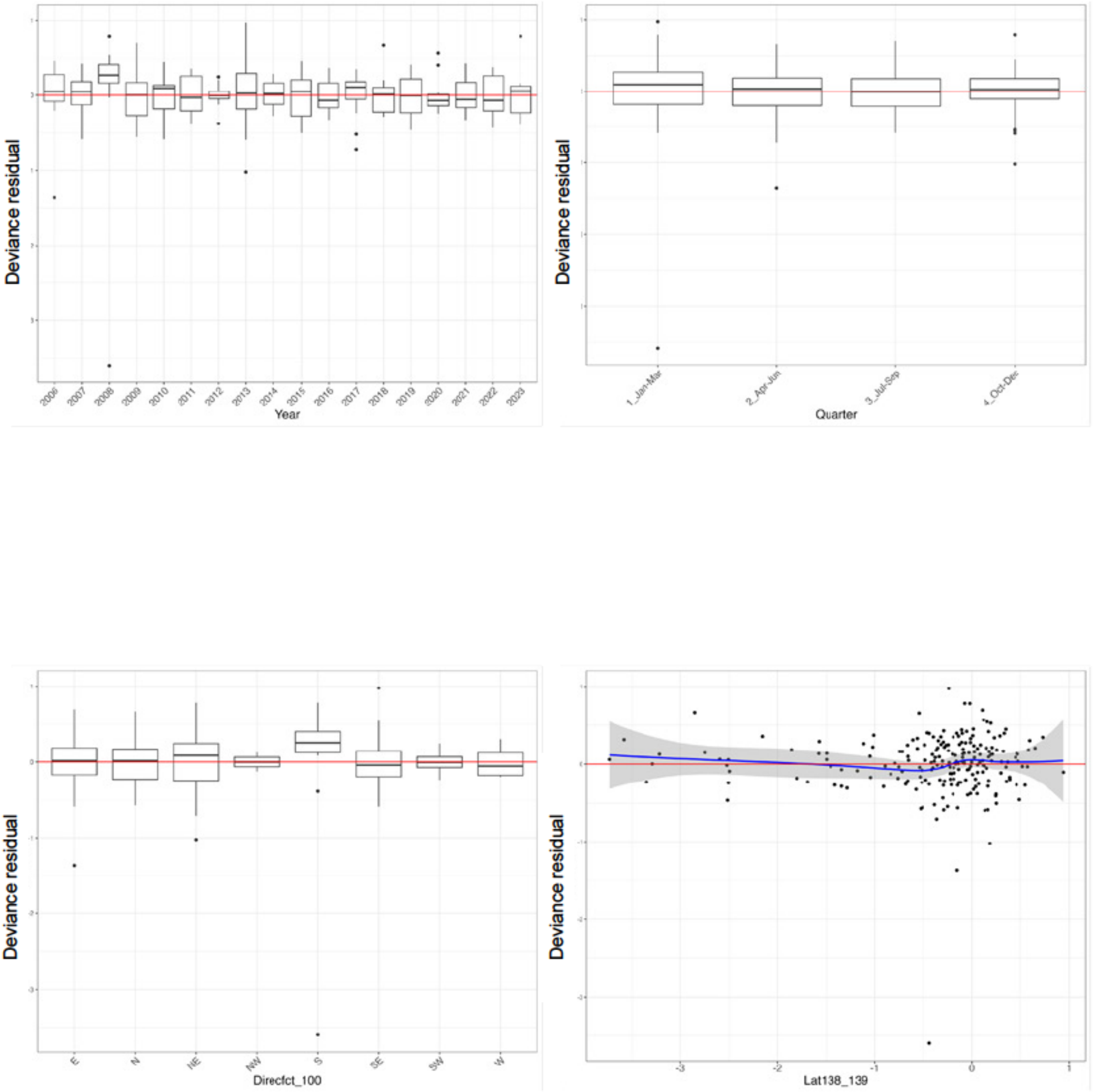

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Lat138_139 represent fitted smoothing curves (loess) and their 95% confidence intervals.

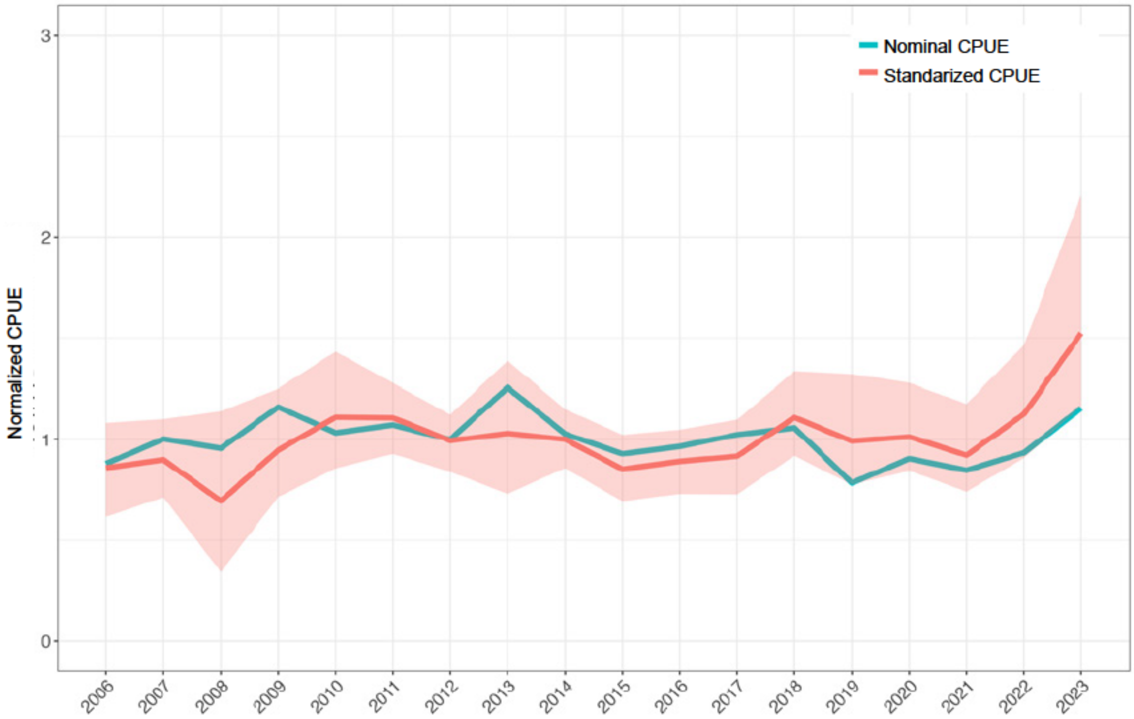

Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Direcfct_100 + Lat138_139 + Quarter + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	4.659	0.133	35.000	0.0000	***
Direcfct_100N	0.109	0.114	0.961	0.3378	
Direcfct_100NE	0.065	0.097	0.668	0.5051	
Direcfct_100NW	0.472	0.346	1.365	0.1740	
Direcfct_100S	-0.515	0.141	-3.655	0.0003	***
Direcfct_100SE	0.042	0.103	0.403	0.6873	
Direcfct_100SW	-0.183	0.242	-0.755	0.4513	
Direcfct_100W	0.173	0.234	0.740	0.4603	
Lat138_139	0.160	0.055	2.923	0.0039	**
Quarter2_Apr-Jun	0.267	0.084	3.176	0.0018	**
Quarter3_Jul-Sep	0.157	0.085	1.848	0.0663	.
Quarter4_Oct-Dec	-0.268	0.085	-3.165	0.0018	**
Year2007	0.045	0.180	0.253	0.8009	
Year2008	-0.212	0.183	-1.159	0.2479	
Year2009	0.097	0.182	0.533	0.5946	
Year2010	0.256	0.187	1.367	0.1731	
Year2011	0.253	0.178	1.421	0.1571	
Year2012	0.146	0.175	0.835	0.4049	
Year2013	0.181	0.184	0.986	0.3252	
Year2014	0.152	0.175	0.867	0.3873	
Year2015	-0.007	0.179	-0.040	0.9682	
Year2016	0.037	0.177	0.207	0.8365	
Year2017	0.065	0.189	0.345	0.7302	
Year2018	0.255	0.210	1.215	0.2258	
Year2019	0.144	0.213	0.675	0.5007	

	Estimate	Standard Error	z value	Pr(>|z|)	
Year2020	0.165	0.196	0.841	0.4015	
Year2021	0.070	0.205	0.343	0.7322	
Year2022	0.270	0.185	1.460	0.1461	
Year2023	0.573	0.201	2.857	0.0048	**

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 0.1802981)

Null deviance: 50.13 on 213 degrees of freedom

Residual deviance: 33.36 on 185 degrees of freedom

AIC: 269.53

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)
Standardization of CPUE for Splendid Alfonsino (Ito Area, Shizuoka Prefecture)

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency

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Summary

Data	Catch and number of landings (day・vessel) data by month for vertical longline fishery of Splendid Alfonsino in Ito Area, Shizuoka Prefecture. Fishing operation location data are not included. Water temperature, direction, and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard's Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day・vessel)
Data availability period	2000-2023
Period used for standardization	2000-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical value as fixed effects) Water temperature, current speed, latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, bottom layer current velocity, the latitude of the northern edge of the Kuroshio in the offshore area (139°E), the latitude difference of the northern edge of Kuroshio between 139°E and 140°E
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects
Calculation method for	Bootstrap sampling of data with replacement, best model

confidence intervals	updates, and annual trend extraction were repeated 1,000 times.
Results of CPUE standardization	Standardized CPUE remained almost flat until around 2009 but decreased from 2010 to 2013. Since then, it has been on a decreasing trend with repeated increases and decreases, but in 2023, it increased compared to the previous year. Although the long-term trend of nominal CPUE was similar to standardized CPUE, the standardized CPUE was significantly higher from 2003 to 2004 and from 2018 onwards.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures to develop more accurate tuning indices. We used “year”, “season”, “area” and “the distance to the Kuroshio axis” (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised by fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables conidering the marine environment, adjusted to the scales (fishing grounds, and entire habitat of the stock) (Watari et al., 2023). As the results of the estimation using data from the Ito Area of Shizuoka Prefecture showed generally acceptable model diagnostic results, demonstrating correction of the lower CPUE due to the effects of the Kuroshio path and current speed in the fishing grounds, it was decided to use the yearly trend derived from this model as one of the tuning indices for the VPA of the Splendid Alfonsino of Pacific Japan.

This fiscal year, as in previous fiscal years, the standardization model for the Ito Area of Shizuoka Prefecture has been updated with the most recent data for the current fiscal year.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Ito Area of Shizuoka Prefecture, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day･vessel) and does not include fishing operation location data. The standardization period was 2000-2023, and all records were used for the analysis.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Ito Area, the latitude of the Kuroshio northern edge at 139°E (Lat_139) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) was calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were used as indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. For the Ito Area, grid number 10 in Fig. 1 was selected as fishing grounds for analysis. However, since the depth at the tenth grid is shallow, only the reanalysis values of water temperature, current direction and current velocity at 0 m depth, 100 m depth and the bottom layer were used. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Direcfct) after monthly averaging. For current direction and current speed,

the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_Bottom +
Speed_0 + Speed_100 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_Bottom +
Lat_139 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.. The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike’s Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The

best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plot, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Quarter + Speed_Bottom + Lat_139 + Lat139_140

For the Ito Area, as a result of the model selection process using an exhaustive search based on AIC, 8 models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. Other models within the minimum AIC+2 range suggested that although water temperature was selected in some cases, all models commonly included bottom layer current velocity, latitude of the northern edge of the Kuroshio at 139°E longitude, and latitudinal difference of Kuroshio northern edge between longitudes 139 to 140. Explanatory variables related to the influence of the Kuroshio and the flow within the fishing grounds were more likely to be selected. The CPUE responses to each of the selected explanatory variables in the best model (Fig. 4) also detected changes in the CPUE influenced by the Kuroshio and current velocity within the fishing grounds.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. Although standardized CPUE fluctuated with increases and decreases after 2000 until around 2009, it tended to remain almost flat during this period but decreased from 2010 to 2013. Since then, it has been on a decreasing trend with repeated increases and decreases, but in 2023, it increased compared to the previous year. Although the long-term trend of nominal CPUE was similar to standardized CPUE, the standardized CPUE was significantly higher from 2003 to 2004 and from 2018 onwards. Nominal CPUE was higher in most of the other years. Notably, the nominal CPUE was significantly higher than the standardized CPUE in 2000, 2001, 2008, 2009, and 2015 to 2017.

3.2 Comparison with the Previous Fiscal Year’s Results

The explanatory variables selected for this fiscal year’s best model were the same as those of the previous fiscal year, and there were no significant differences from the previous year in the standardized CPUE trends derived from the best model.

Cited literature

Kuroda, H., Setou, T., Kakehi, S., Ito, S., Taneda, T., Azumaya, T., Inagake, D., Hiroe, Y., Morinaga, K., Okazaki, M., Yokota, T., Okunishi, T., Aoki, K., Shimizu, Y., Hasegawa, D., and Watanabe, T. (2017) Recent advances in Japanese fisheries science in the Kuroshio-Oyashio region through development of the FRA-ROMS ocean forecast system: Overview of the reproducibility of reanalysis products. Open Journal of Marine Science, 7, 62–90.

Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

Watari, S. and Hanzawa, Y. (2022) FY 2021 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FY 2021 Fisheries Stock Assessment in the Waters around Japan, Japan Fisheries Research and Education Society, Fisheries Agency. FRA-SA2021-RC02-2. https://abchan.fra.go.jp/wpt/wp-content/uploads/2021/details_2021_37.pdf

Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction			Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed			Water temperature			Sea-son	Year	df	logLik	AIC	delta
	0	100	Bottom	138°E	138-139	139-140	140-141	0	100	Bottom	0	100	Bottom						
9.58				-0.16		0.12				-3.91	-0.02			+	+	32	-72.7	209.4	0.0
9.47				-0.16		0.13				-4.04				+	+	31	-73.9	209.7	0.3
9.09			+	-0.14		0.11				-4.64	-0.02			+	+	39	-66.5	211.0	1.6
9.13				-0.14	0.02	0.12				-3.86	-0.02			+	+	33	-72.5	211.0	1.6
9.21				-0.16		0.13				-3.95			0.02	+	+	32	-73.5	211.0	1.6
8.95			+	-0.15		0.11				-4.74				+	+	38	-67.6	211.1	1.7
9.02				-0.15	0.02	0.12				-3.98				+	+	32	-73.6	211.3	1.9
9.75				-0.16		0.13	0.01			-3.89	-0.02			+	+	33	-72.7	211.4	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2000	1.63	1.53	1.31	1.78	0.08
2001	1.54	1.33	1.12	1.55	0.09
2002	0.94	0.98	0.80	1.22	0.11
2003	1.22	1.34	1.14	1.57	0.08
2004	1.10	1.21	0.96	1.48	0.11
2005	1.35	1.29	0.96	1.70	0.14
2006	1.60	1.66	1.44	1.94	0.08
2007	1.35	1.35	1.17	1.53	0.07
2008	1.40	1.33	1.12	1.57	0.08
2009	1.43	1.26	1.07	1.49	0.08
2010	1.01	1.03	0.83	1.25	0.11
2011	1.07	1.10	0.92	1.28	0.09
2012	0.93	0.91	0.72	1.12	0.11
2013	0.75	0.69	0.58	0.82	0.09
2014	0.90	0.90	0.76	1.06	0.08
2015	0.92	0.83	0.71	0.95	0.07
2016	1.04	0.96	0.77	1.22	0.12
2017	0.88	0.80	0.67	0.95	0.09
2018	0.63	0.66	0.56	0.76	0.08
2019	0.40	0.50	0.41	0.58	0.08
2020	0.49	0.63	0.49	0.79	0.12
2021	0.64	0.78	0.63	0.93	0.10
2022	0.35	0.40	0.30	0.52	0.14
2023	0.43	0.53	0.40	0.68	0.13

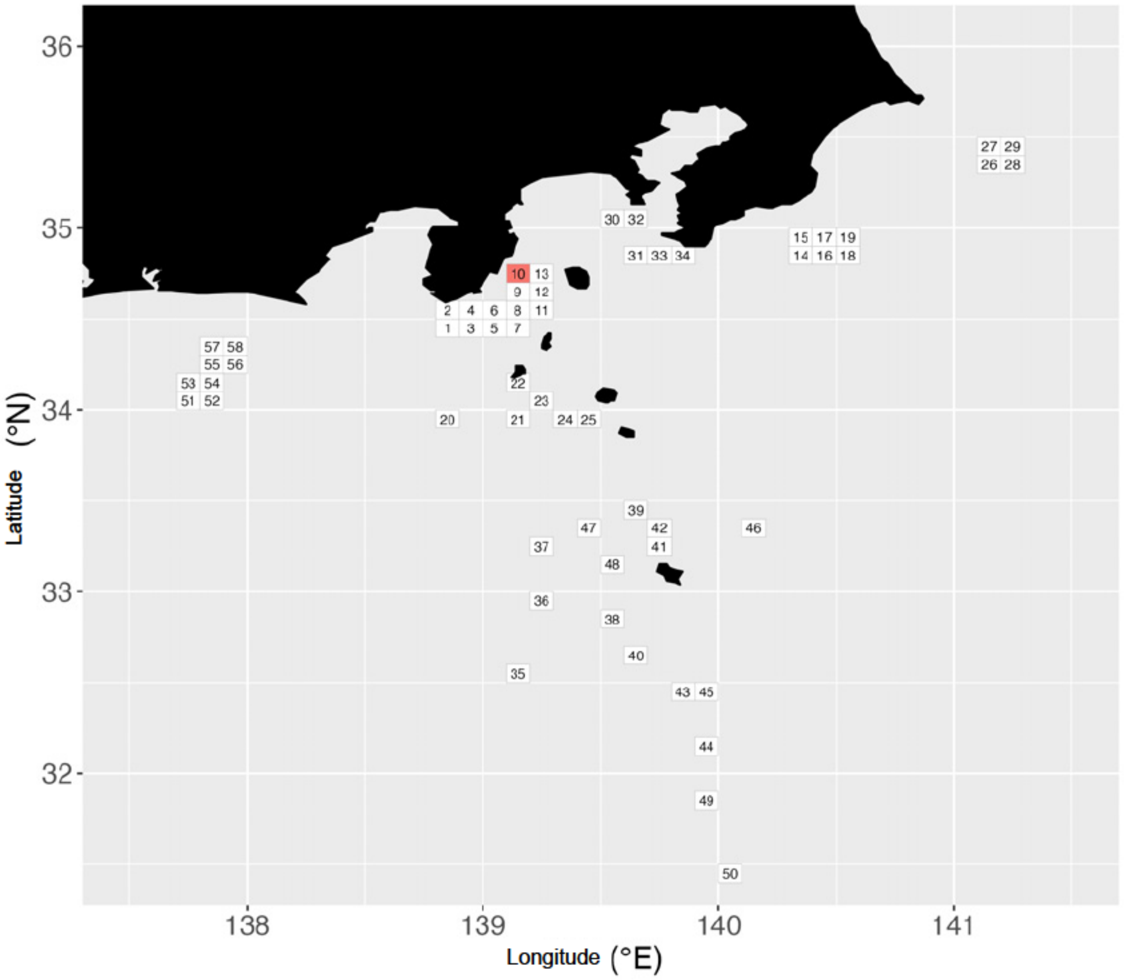

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values - Data extracted for 0.1° grid units of latitude and longitude. For the Ito Area, grid number 10 was used.

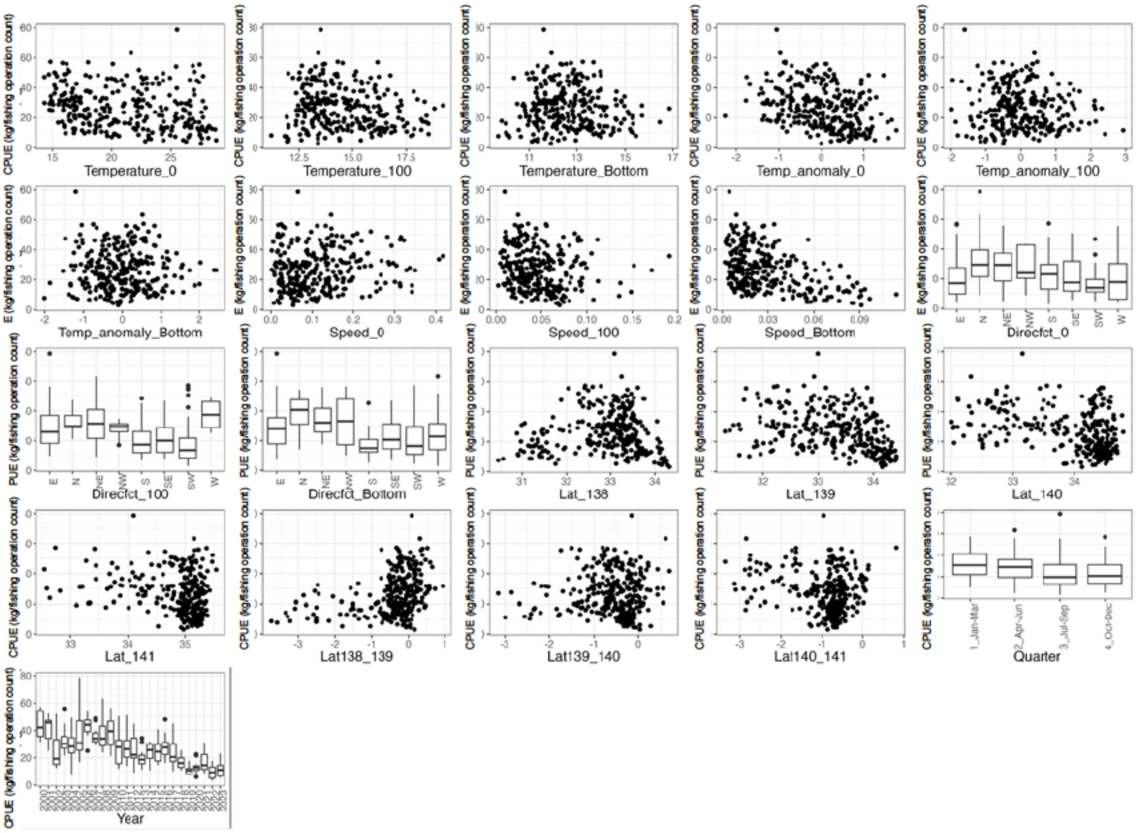

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

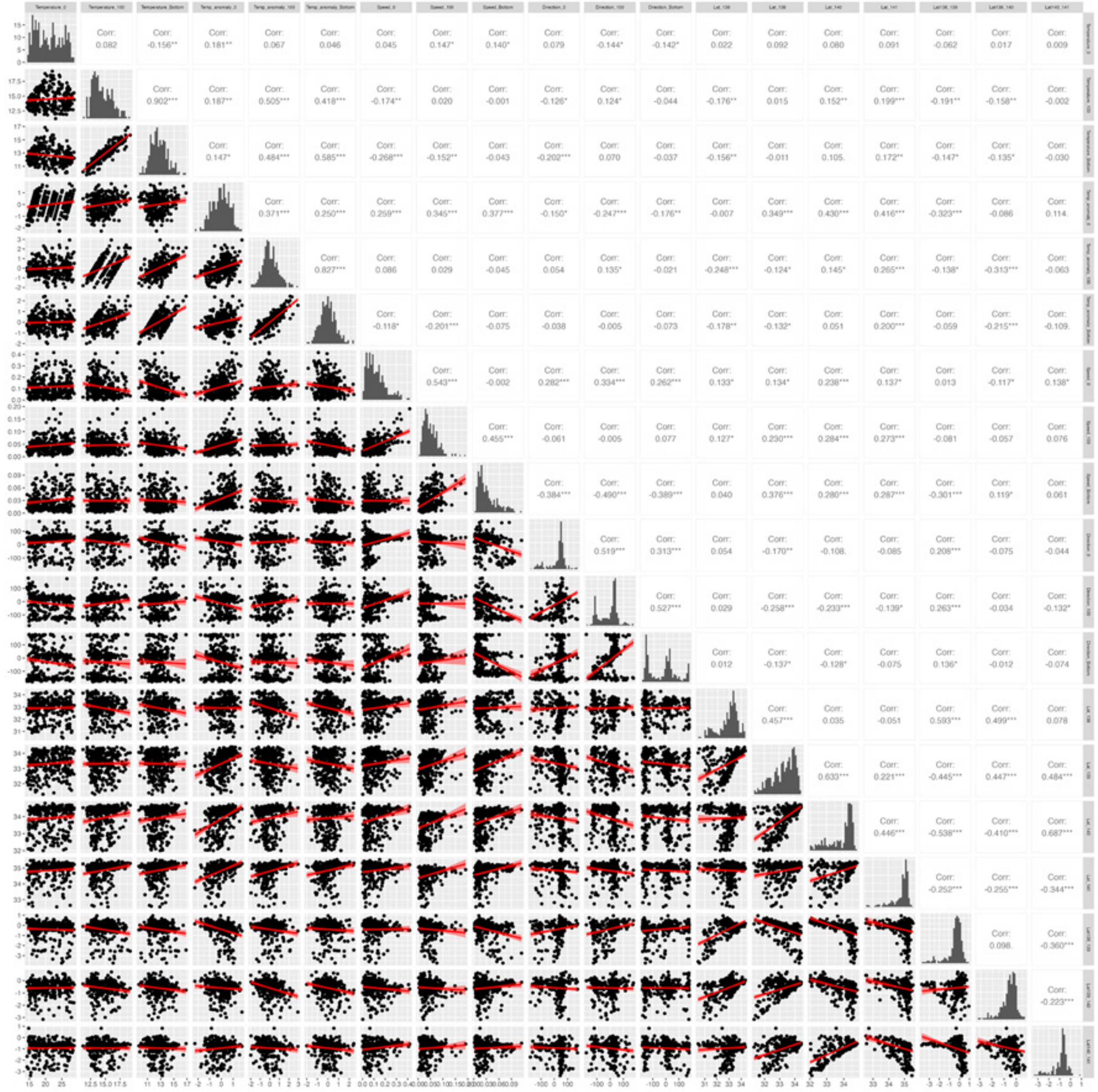

Fig. 3. Correlation between the marine environmental data used in the standardization model

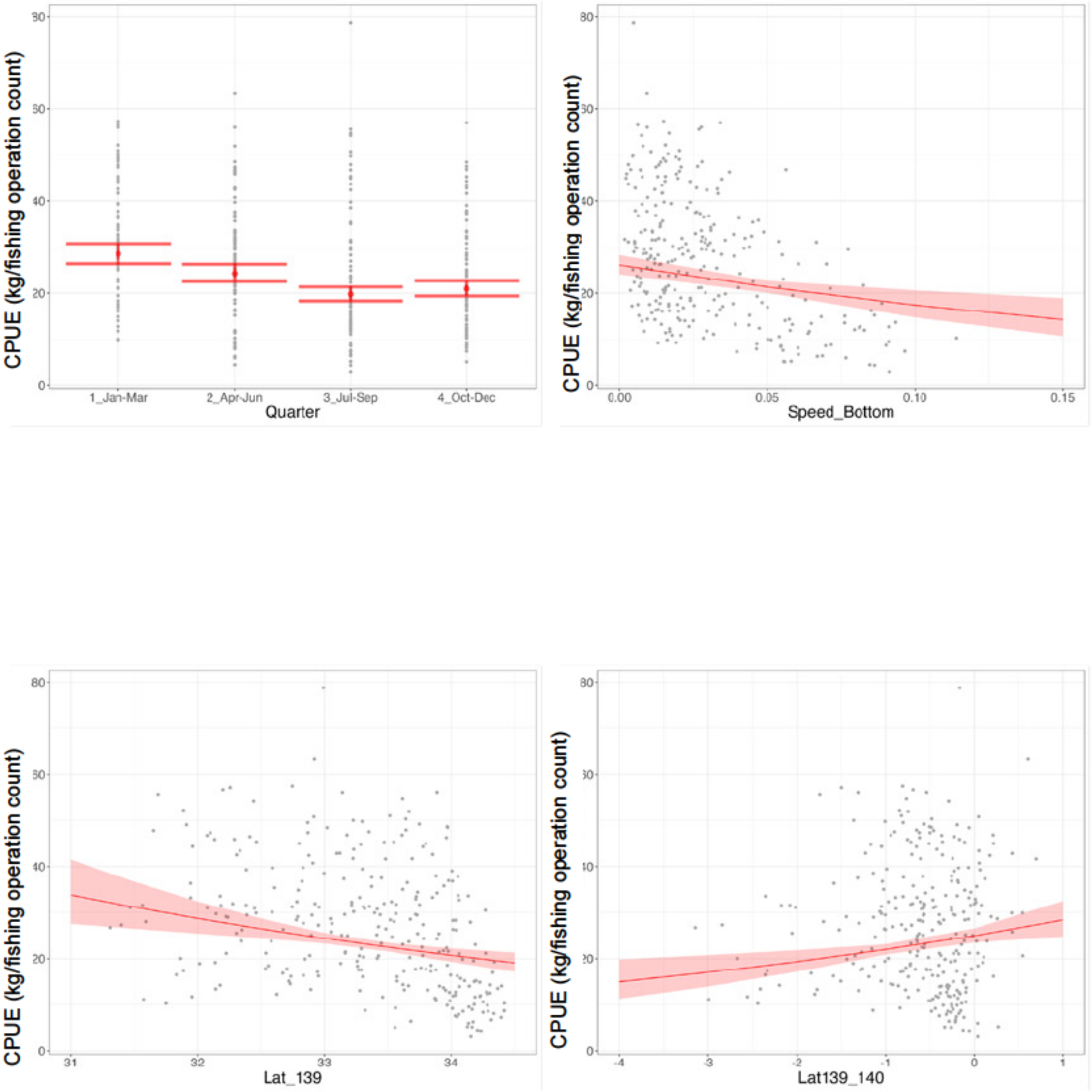

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

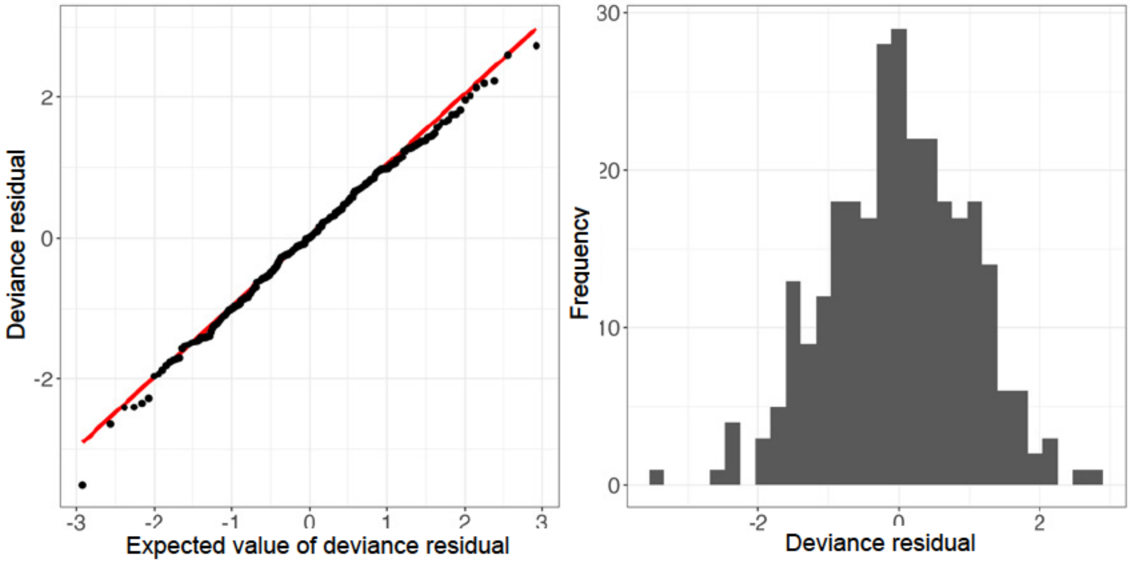

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

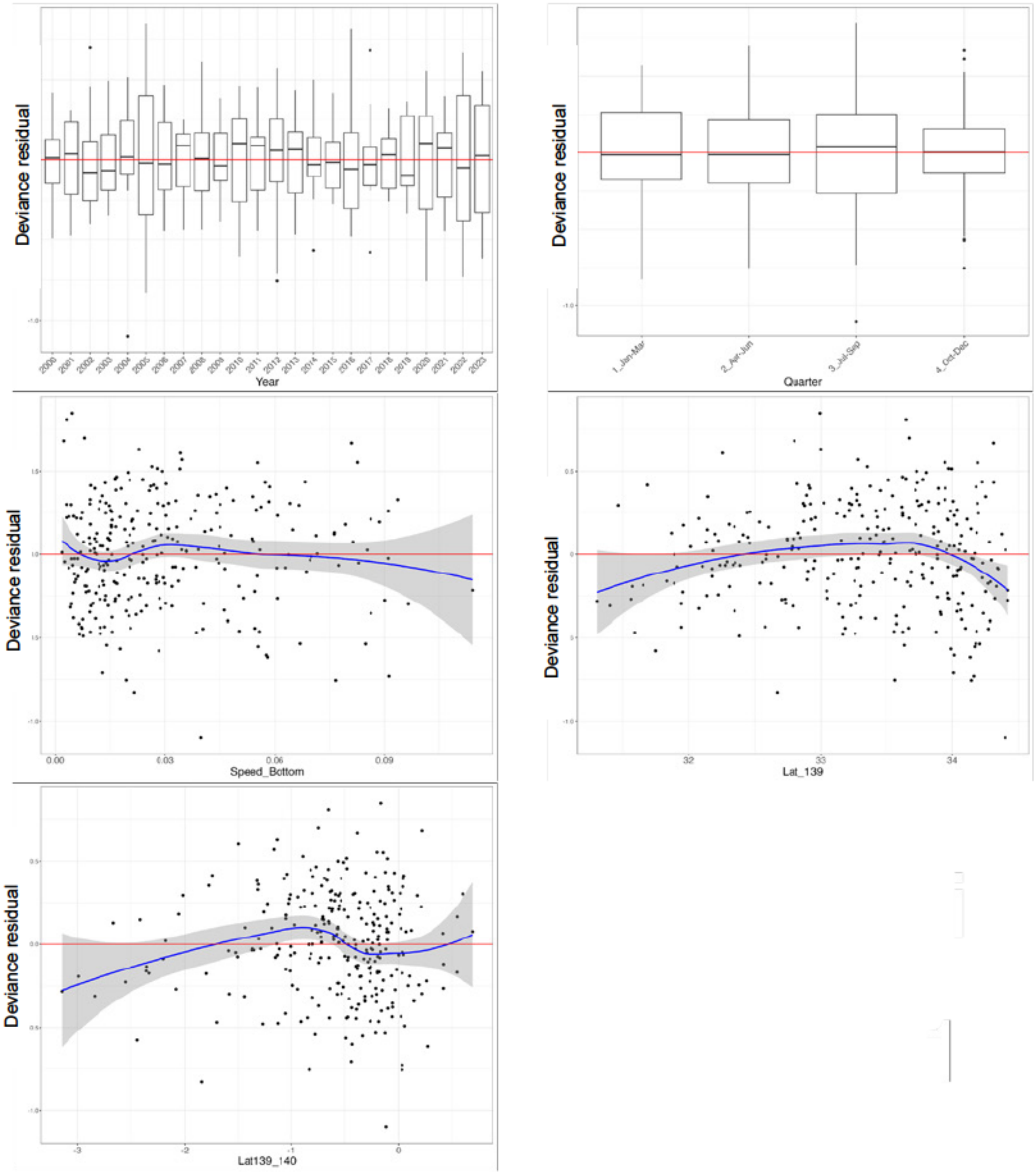

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Speed_Bottom, Lat_139, and Lat139_140 represent fitted smoothing curves (loess) and their 95% confidence intervals.

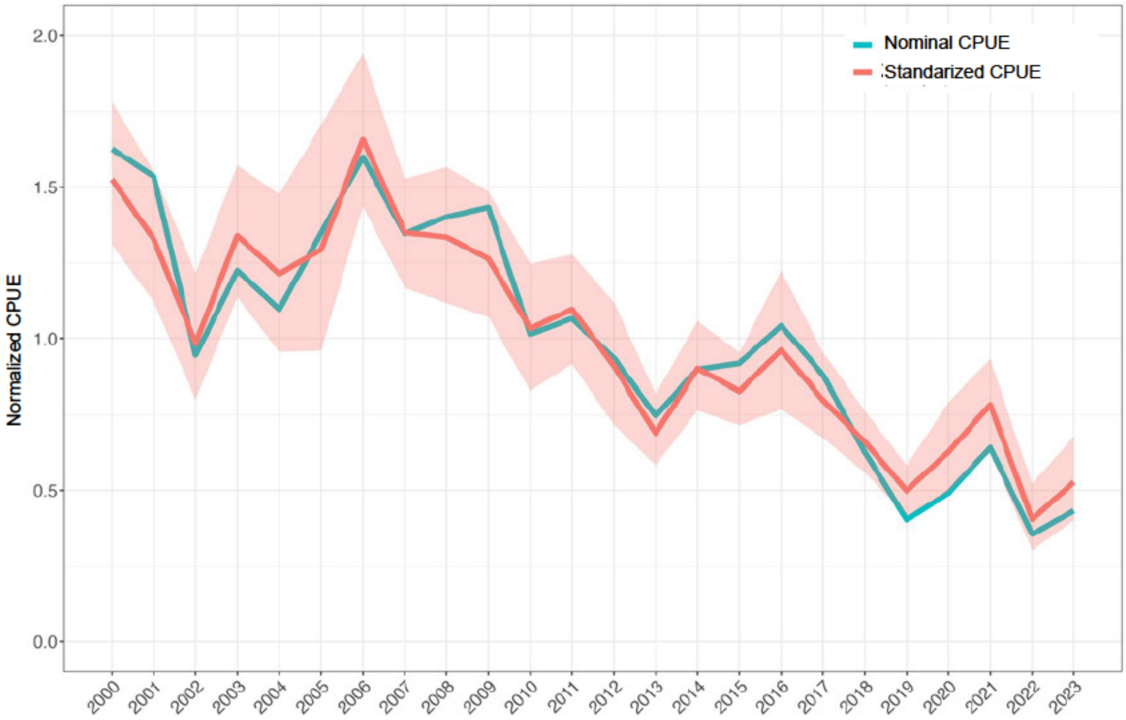

Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Lat_139 + Lat139_140 + Quarter + Speed_Bottom + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	9.465	1.450	6.528	0.0000	***
Lat_139	-0.163	0.044	-3.709	0.0003	***
Lat139_140	0.128	0.041	3.096	0.0022	**
Quarter2_Apr-Jun	-0.159	0.055	-2.874	0.0044	**
Quarter3_Jul-Sep	-0.365	0.055	-6.596	0.0000	***
Quarter4_Oct-Dec	-0.308	0.056	-5.544	0.0000	***
Speed_Bottom	-4.035	1.188	-3.397	0.0008	***
Year2001	-0.139	0.136	-1.020	0.3085	
Year2002	-0.439	0.146	-3.010	0.0029	**
Year2003	-0.130	0.145	-0.898	0.3702	
Year2004	-0.229	0.148	-1.542	0.1243	
Year2005	-0.165	0.137	-1.206	0.2290	
Year2006	0.083	0.140	0.596	0.5519	
Year2007	-0.122	0.136	-0.899	0.3698	
Year2008	-0.134	0.137	-0.978	0.3288	
Year2009	-0.189	0.137	-1.380	0.1689	
Year2010	-0.390	0.142	-2.759	0.0062	**
Year2011	-0.331	0.141	-2.344	0.0198	*
Year2012	-0.518	0.139	-3.727	0.0002	***
Year2013	-0.795	0.137	-5.818	0.0000	***
Year2014	-0.526	0.138	-3.812	0.0002	***
Year2015	-0.613	0.136	-4.507	0.0000	***
Year2016	-0.462	0.136	-3.395	0.0008	***
Year2017	-0.649	0.135	-4.805	0.0000	***
Year2018	-0.838	0.141	-5.941	0.0000	***

	Estimate	Standard Error	z value	Pr(>|z|)	
Year2019	-1.118	0.147	-7.586	0.0000	***
Year2020	-0.889	0.156	-5.686	0.0000	***
Year2021	-0.667	0.152	-4.401	0.0000	***
Year2022	-1.328	0.153	-8.660	0.0000	***
Year2023	-1.062	0.157	-6.783	0.0000	***

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 0.1091517)

Null deviance: 98.08 on 287 degrees of freedom

Residual deviance: 28.16 on 258 degrees of freedom

AIC: 209.7

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)
Standardization of CPUE for Splendid Alfonsino (Inatori Area, Shizuoka Prefecture)

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency
Yohei Kawauchi, Aigo Takeshige, Shingo Watari, Shion Takemura, Kazuhiro Aoki, Hitomi Oyaizu

Summary

Data	Catch and number of landings (day･vessel) data by month for vertical longline fishery of Splendid Alfonsino in Inatori Area, Shizuoka Prefecture. Fishing operation location data are not included. Water temperature, direction, and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard's Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day･vessel)
Data availability period	2000-2023
Period used for standardization	2000-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical value as fixed effects) Water temperature, current speed, latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, season, water temperature at 0 m depth layer, current velocity at 0 m depth layer
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects
Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.
Results of CPUE	Standardized CPUE remained almost flat until around 2009 but

standardization	declined thereafter. After 2018, it began to increase again, and in 2021, it was estimated to be at the same level as the maximum during the analysis period. However, CPUE decreased after 2022, reaching the same level as it was during 2013 to 2018 in 2023. Although the long-term trend of nominal CPUE was similar to standardized CPUE, the standardized CPUE was higher from 2004 to 2005 and from 2018 onwards.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We used “year”, “season”, “area”, and the distance to the Kuroshio axis (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raised by fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock calculation because the effects of proximity to the Kuroshio could not be adequately eliminated; fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds, entire distribution area) (Watari et al., 2023). As the results of the estimation using data from the Inatori Area of Shizuoka Prefecture showed generally favorable model diagnostic results, demonstrating correction of the lower CPUE due to the effects of the Kuroshio and current speed in the fishing grounds, it was decided to use the yearly trend derived from this model as one of the tuning indices for the VPA of the Splendid Alfonsino of Pacific Japan.

This fiscal year, as in previous fiscal years, the standardization model for the Inatori Area of Shizuoka Prefecture has been updated with the most recent data for the current fiscal year.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Inatori Area of Shizuoka Prefecture, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day･vessel) and does not include fishing operation location data. The standardization period was 2000-2023, and all records were used for the analysis.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Inatori Area, the latitude of the Kuroshio northern edge at 139°E (Lat_139) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) Calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were used as indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. For the Inatori Area, grid number 8 in Fig. 1 was selected as fishing grounds for analysis. However, since the depth at the eighth grid is shallow, only the reanalysis values of water temperature, current direction and current velocity at 0 m depth, 100 m depth, 200 m depth and the bottom layer were used. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Direcfct) after monthly averaging. For current direction and current speed,

the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.

Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.

Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_Bottom +
Lat_139 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.. The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses.

2.3 Model Selection

The best model was determined through Akaike’s Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plot, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Quarter + Temperature_0 + Speed_0

For the Inatori Area, as a result of the model selection process using an exhaustive search based on AIC, 10 models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. Other models within the minimum AIC+2 range suggested that many models commonly included 0 m current velocity, 0 m water temperature, and latitudinal difference of Kuroshio’s northern edge between longitudes 139 to 140. Explanatory variables related to the influence of the Kuroshio and the flow within the fishing grounds were more likely to be selected. The CPUE responses to each of the selected explanatory variables in the best model (Fig. 4) also detected changes in the CPUE caused by current velocity within the fishing grounds and water temperature.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. Although standardized CPUE fluctuated with increases and decreases after 2000 until around 2009, it tended to remain almost flat during this period but declined thereafter. After 2018, CPUE began to increase again, and in 2021, it was estimated to be at the same level as the maximum value during the analysis period recorded in 2005. CPUE decreased after 2022, and in 2023, it was estimated to have returned to the same level as from 2013 to 2018. Although the long-term trend of nominal CPUE was similar to standardized CPUE, the standardized CPUE was higher from 2004 to 2005 and from 2018 onwards. Nominal CPUE was higher in most of the other years. Notably, the nominal CPUE was significantly higher than the standardized CPUE in 2000, 2001, 2009, and 2014 to 2016.

3.2 Comparison with the Previous Fiscal Year’s Results

As in the previous fiscal year, the latitude difference between the northern edge of the Kuroshio at longitudes 139 to 140 degrees east and the seasonal effect was included in the best model. On the other hand, 0 m water temperature, which was not included in the previous fiscal year’s best model, has been added this year. However, the 200 m current speed included in the previous fiscal year has been excluded this year. However, in any of the given years, many models within the minimum AIC+2 range include 0 m water temperature and 200 m current direction. Moreover, since the changes in the annual trends of standardized CPUE based on the best model are also small, it can be concluded that the addition of one year of data did not result in significant changes in the model estimation results.

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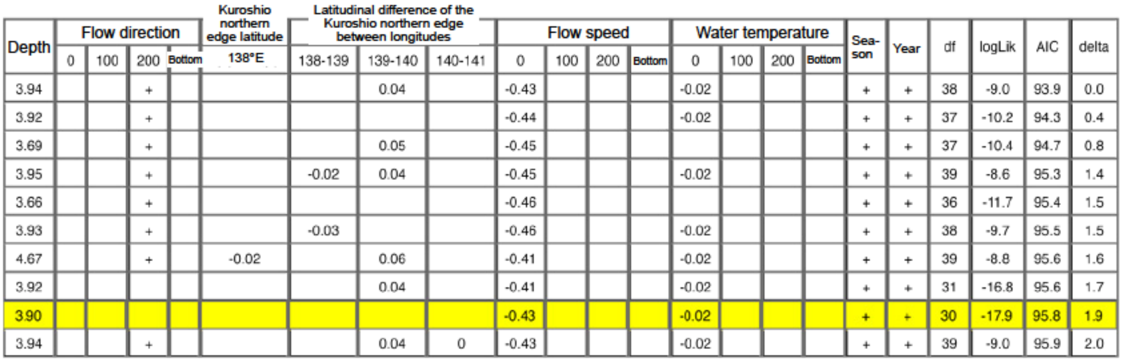
Kuroda, H., Setou, T., Kakehi, S., Ito, S., Taneda, T., Azumaya, T., Inagake, D., Hiroe, Y., Morinaga, K., Okazaki, M., Yokota, T., Okunishi, T., Aoki, K., Shimizu, Y., Hasegawa, D., and Watanabe, T. (2017) Recent advances in Japanese fisheries science in the Kuroshio-Oyashio region through development of the FRA-ROMS ocean forecast system: Overview of the reproducibility of reanalysis products. Open Journal of Marine Science, 7, 62–90.

Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

Watari S, Hanzawa Y (2022) FY 2021 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FY 2021 Fisheries Stock Assessment in the Waters around Japan, Japan Fisheries Research and Education Society, Fisheries Agency. FRA-SA2021-RC02-2. https://abchan.fra.go.jp/wpt/wp-content/uploads/2021/details_2021_37.pdf

Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.



Depth	Flow direction				Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed				Water temperature				Sea-son	Year	df	logLik	AIC	delta
	0	100	200	Bottom	138°E	138-139	139-140	140-141	0	100	200	Bottom	0	100	200	Bottom						
3.94			+				0.04		-0.43				-0.02				+	+	38	-9.0	93.9	0.0
3.92			+						-0.44				-0.02				+	+	37	-10.2	94.3	0.4
3.69			+				0.05		-0.45								+	+	37	-10.4	94.7	0.8
3.95			+			-0.02	0.04		-0.45				-0.02				+	+	39	-8.6	95.3	1.4
3.66			+						-0.46								+	+	36	-11.7	95.4	1.5
3.93			+			-0.03			-0.46				-0.02				+	+	38	-9.7	95.5	1.5
4.67			+		-0.02		0.06		-0.41				-0.02				+	+	39	-8.8	95.6	1.6
3.92							0.04		-0.41				-0.02				+	+	31	-16.8	95.6	1.7
3.90									-0.43				-0.02				+	+	30	-17.9	95.8	1.9
3.94			+				0.04	0	-0.43				-0.02				+	+	39	-9.0	95.9	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2000	1.16	1.04	0.82	1.30	0.11
2001	1.25	1.10	0.97	1.26	0.07
2002	1.00	0.94	0.79	1.12	0.09
2003	1.19	1.18	1.08	1.28	0.04
2004	1.07	1.29	1.08	1.55	0.09
2005	1.34	1.35	1.22	1.50	0.05
2006	1.20	1.04	0.93	1.17	0.06
2007	1.05	1.04	0.93	1.16	0.05
2008	1.24	1.23	1.10	1.36	0.05
2009	1.42	1.22	1.05	1.38	0.07
2010	1.05	1.04	0.90	1.19	0.07
2011	0.95	0.93	0.83	1.05	0.06
2012	1.06	1.03	0.90	1.18	0.07
2013	0.76	0.70	0.58	0.81	0.08
2014	0.90	0.78	0.62	0.93	0.10
2015	0.83	0.76	0.65	0.87	0.07
2016	0.86	0.76	0.66	0.88	0.08
2017	0.75	0.71	0.61	0.81	0.07
2018	0.64	0.72	0.62	0.84	0.08
2019	0.74	0.93	0.74	1.18	0.12
2020	0.94	1.13	0.89	1.37	0.11
2021	1.07	1.30	1.09	1.52	0.09
2022	0.87	1.01	0.89	1.15	0.07
2023	0.64	0.76	0.61	0.92	0.11

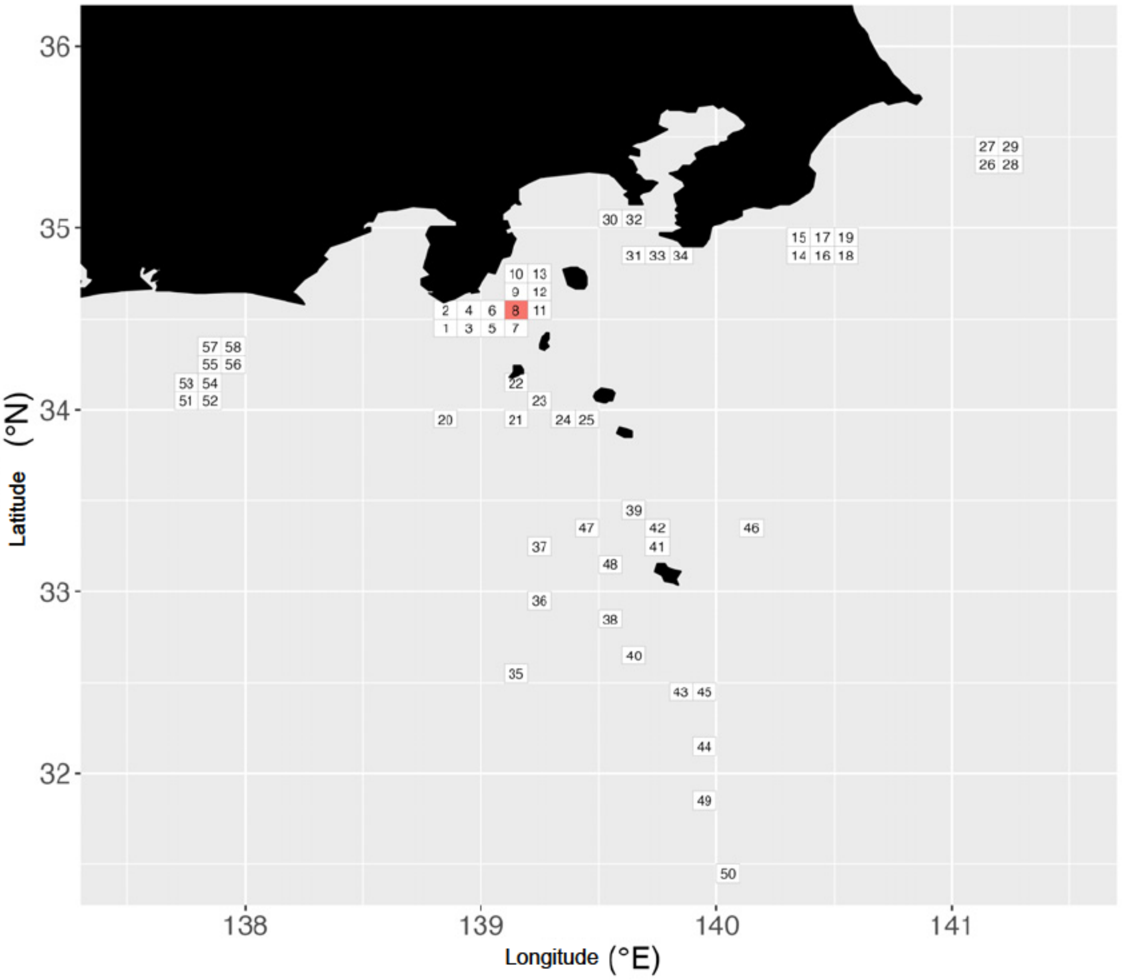


Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values -
Data extracted for 0.1° grid units of latitude and longitude
For the Inatori Area, grid number 8 was used.

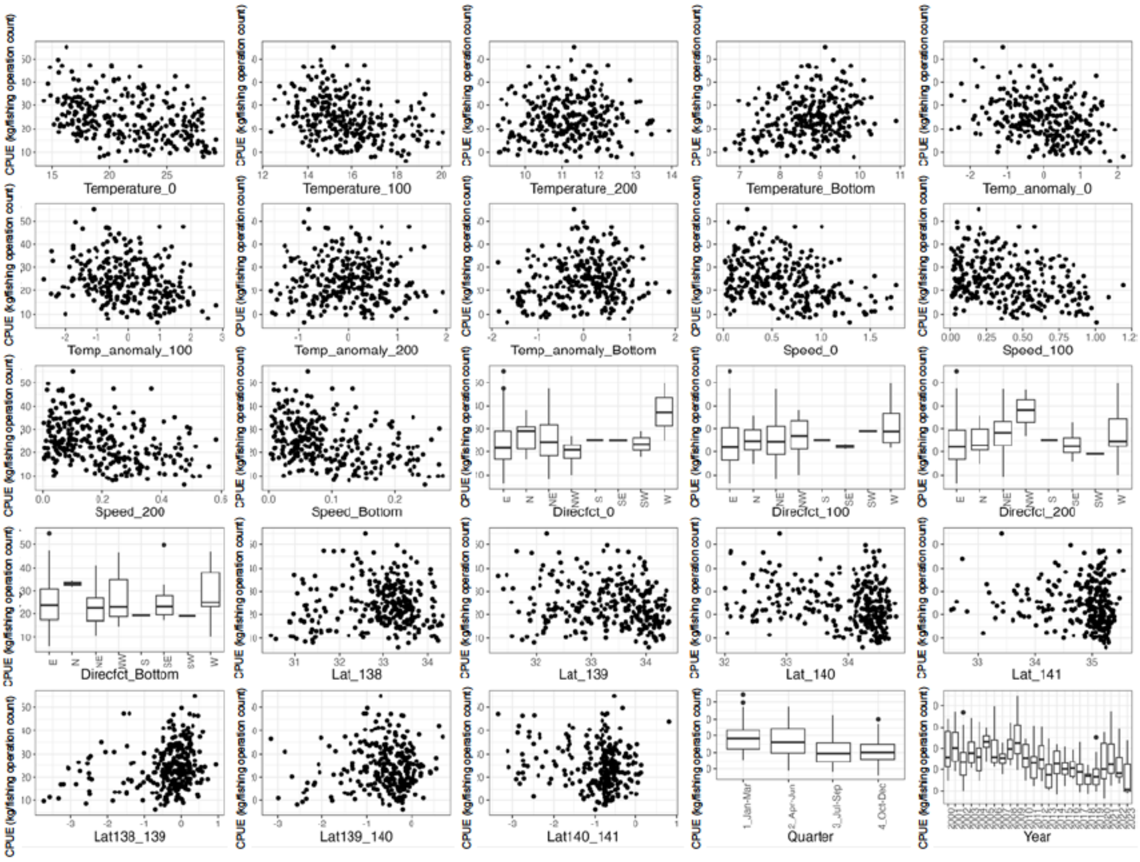


Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

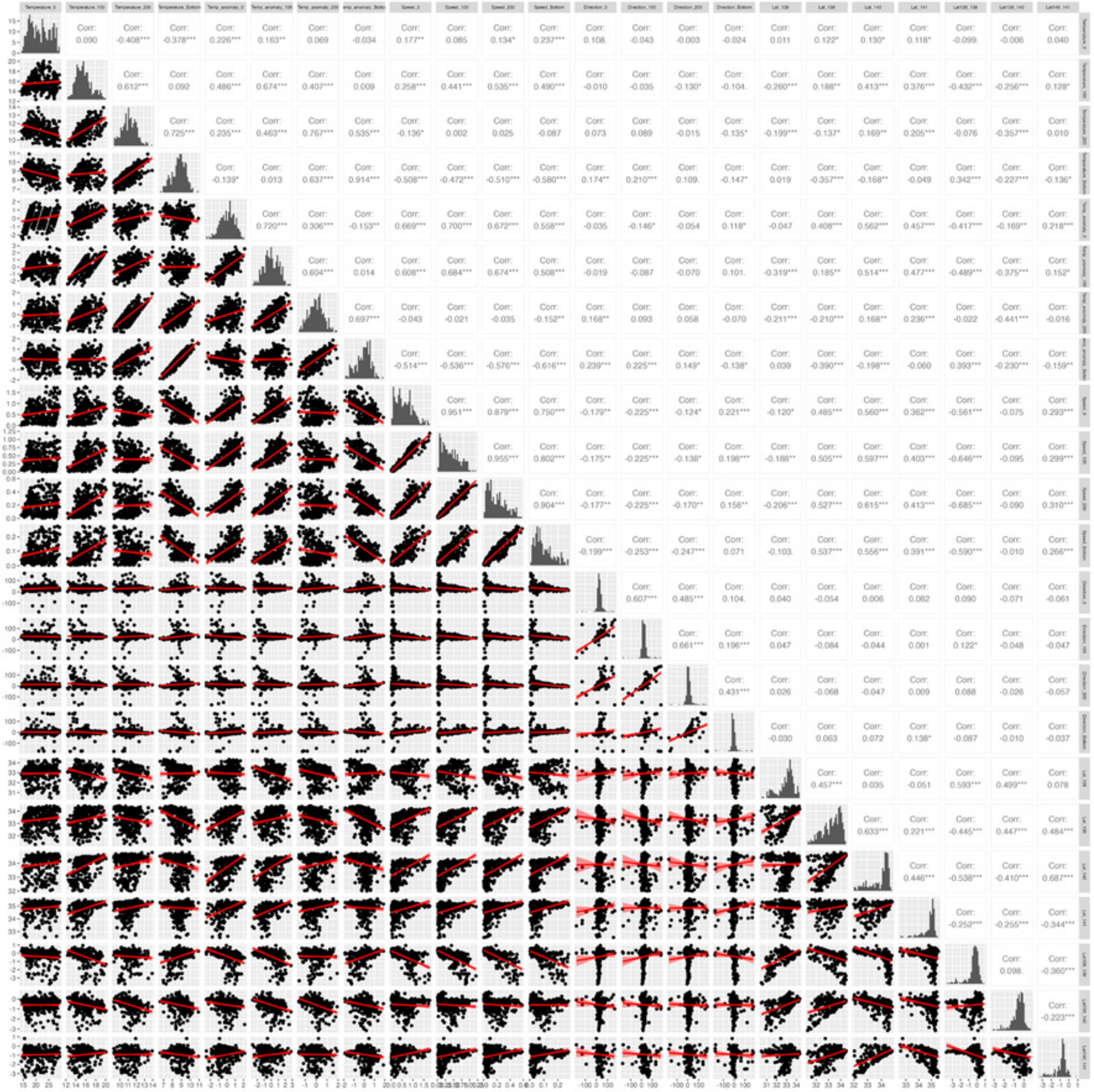


Fig. 3. Correlation between the marine environmental data used in the standardization model

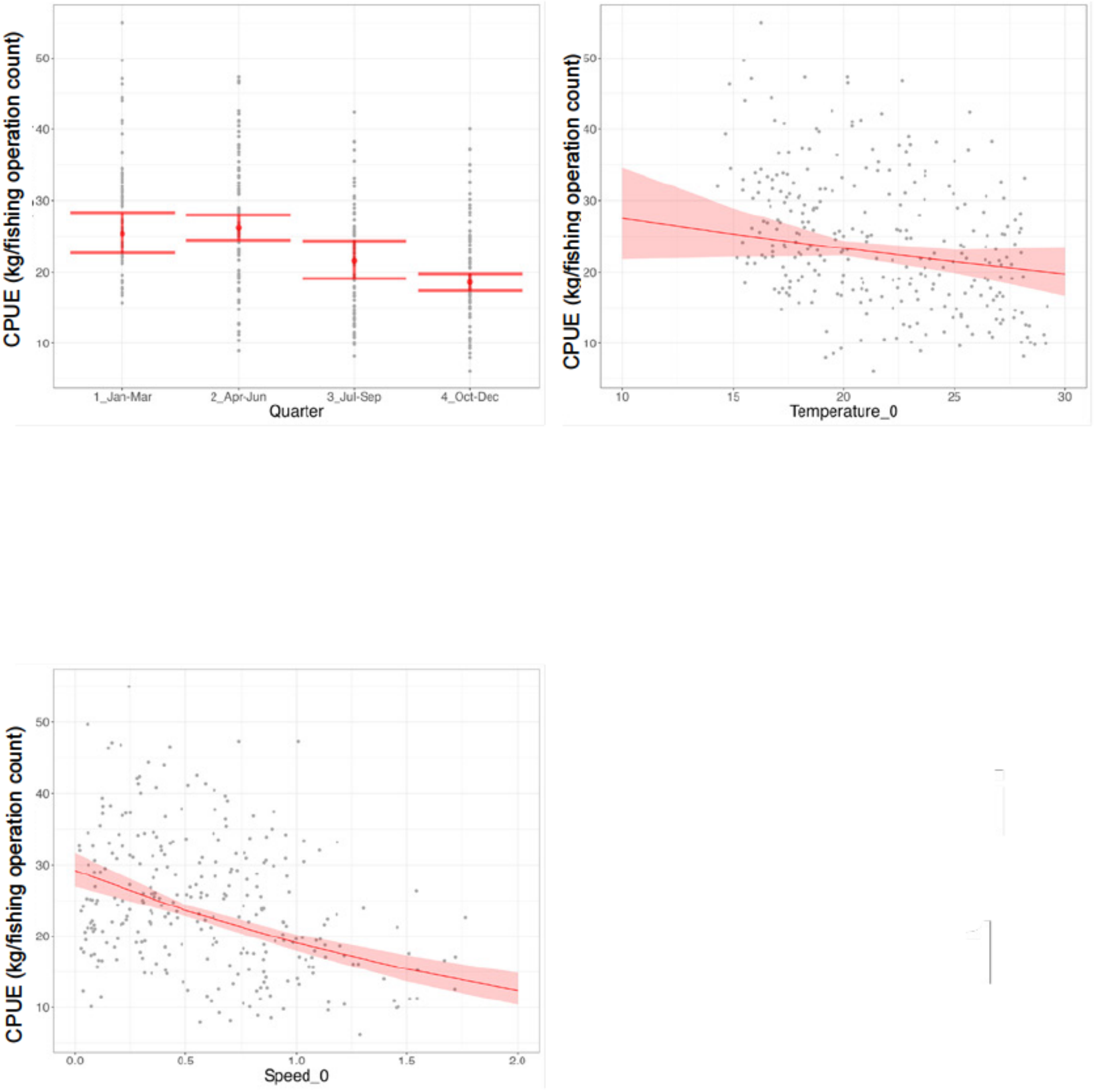


Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

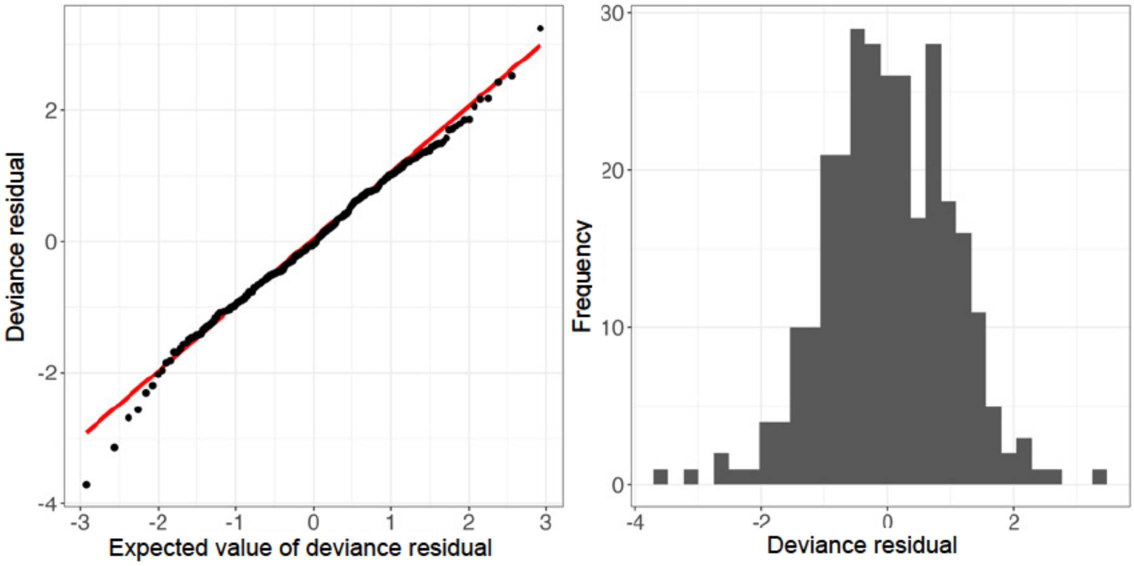


Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

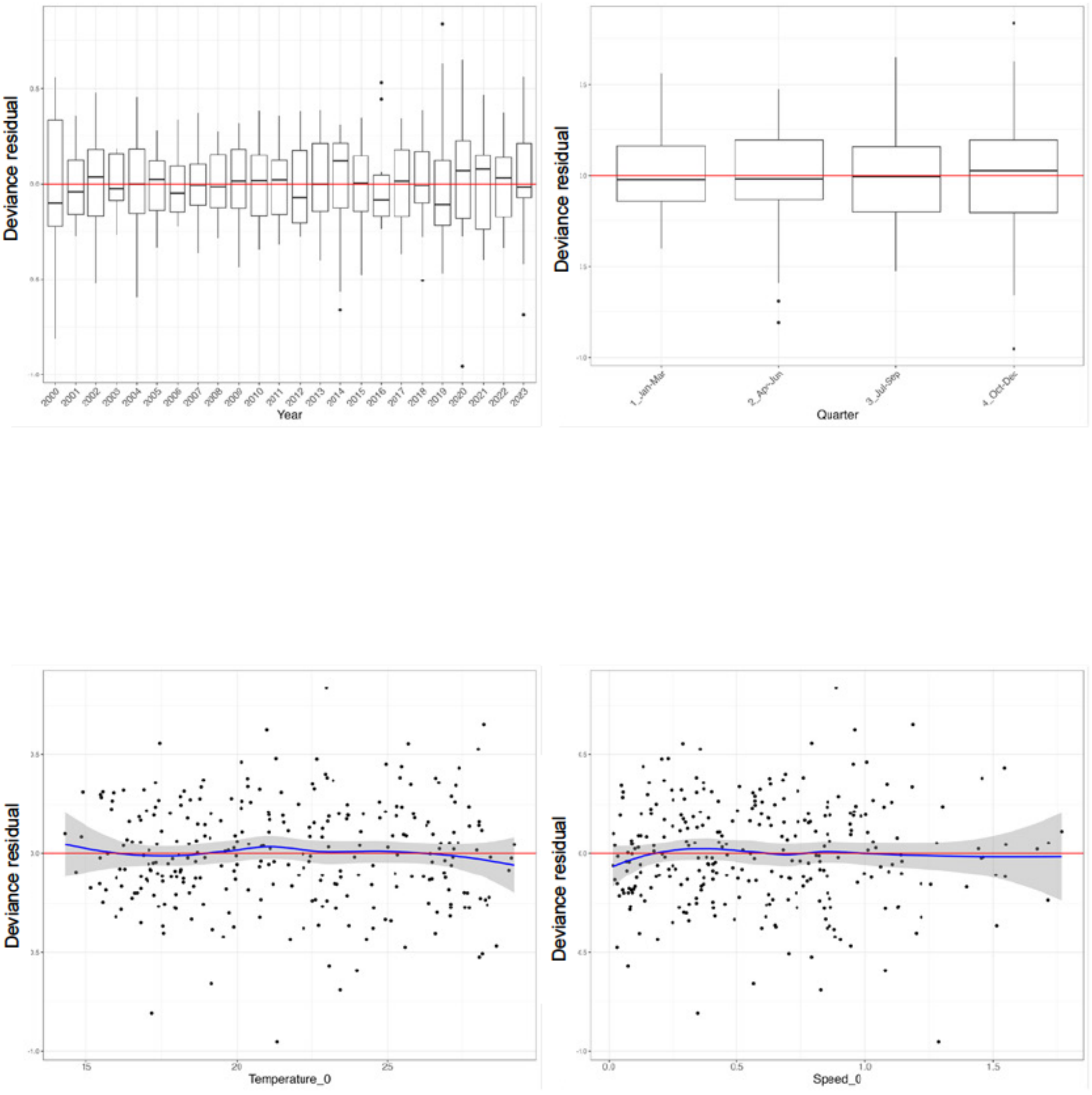


Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Temperature_0 and Speed_0 represent fitted smoothing curves (loess) and their 95% confidence intervals.

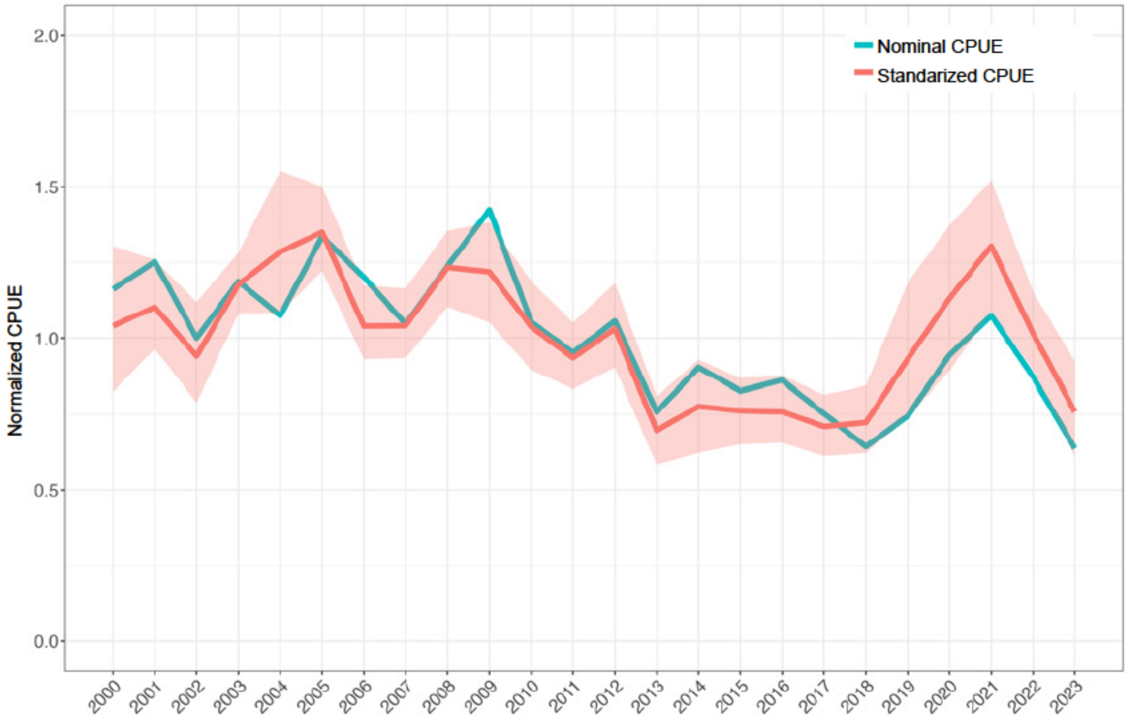


Fig. 7. Transition of standardized and nominal CPUE, with CPUE values normalized by the mean value over the analysis period

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model

glm(formula = log(CPUE) ~ Quarter + Speed_0 + Temperature_0 + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	3.901	0.183	21.307	0.0000	***
Quarter2_Apr-Jun	0.032	0.057	0.560	0.5757	
Quarter3_Jul-Sep	-0.162	0.110	-1.479	0.1403	
Quarter4_Oct-Dec	-0.313	0.069	-4.506	0.0000	***
Speed_0	-0.428	0.064	-6.733	0.0000	***
Temperature_0	-0.016	0.010	-1.636	0.1030	
Year2001	0.058	0.111	0.524	0.6007	
Year2002	-0.101	0.112	-0.902	0.3676	
Year2003	0.124	0.111	1.111	0.2674	
Year2004	0.211	0.117	1.806	0.0721	.
Year2005	0.261	0.111	2.345	0.0198	*
Year2006	-0.000	0.111	-0.002	0.9987	
Year2007	0.001	0.111	0.008	0.9938	
Year2008	0.171	0.111	1.535	0.1261	
Year2009	0.159	0.111	1.430	0.1541	
Year2010	-0.002	0.111	-0.020	0.9841	
Year2011	-0.107	0.112	-0.957	0.3395	
Year2012	-0.009	0.111	-0.082	0.9348	
Year2013	-0.401	0.111	-3.610	0.0004	***
Year2014	-0.293	0.111	-2.643	0.0087	**
Year2015	-0.311	0.111	-2.806	0.0054	**
Year2016	-0.316	0.111	-2.840	0.0049	**
Year2017	-0.382	0.111	-3.435	0.0007	***
Year2018	-0.364	0.114	-3.183	0.0016	**
Year2019	-0.111	0.120	-0.925	0.3560	

	Estimate	Standard Error	z value	Pr(>|z|)	
Year2020	0.084	0.120	0.696	0.4870	
Year2021	0.226	0.120	1.884	0.0608	.
Year2022	-0.025	0.116	-0.212	0.8320	
Year2023	-0.316	0.120	-2.633	0.0090	**

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 0.07371695)

Null deviance: 46.08 on 287 degrees of freedom

Residual deviance: 19.09 on 259 degrees of freedom

AIC: 95.78

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141

Stock Assessment for the Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)
Standardization of CPUE for Splendid Alfonsino (Omaezaki Area, Shizuoka Prefecture)

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency
Yohei Kawauchi, Aigo Takeshige, Shingo Watari, Shion Takemura, Kazuhiro Aoki, Hitomi Oyaizu

Summary

Data	Catch and number of landings (day･vessel) data by month for vertical longline fishery of Splendid Alfonsino in Omaezaki Area, Shizuoka Prefecture. Fishing operation location data are not included. Water temperature, direction, and speed of sea current in the fishing grounds were obtained from FRA-ROMS II. Information on the Kuroshio current path was extracted from Japan Coast Guard's Quick Bulletin of Ocean Conditions
Analysis target	Catch per day, per vessel (kg/day･vessel)
Data availability period	2002-2023
Period used for standardization	2002-2023
Data extraction	All records were used
Statistical software and analytical packages used	The analysis was conducted using R version 4.4.0, with the following packages: stats 4.4.0 (for GLM calculations), MuMIn 1.47.5 (for model selection), readxl 1.4.3 (for reading Excel files), tidyverse 2.0.0 (for data processing and visualizing, including model diagnostic results), GGally 2.2.1 (for visualizing), gridExtra 2.3 (for visualizing), lubridate 1.9.3 (for handling time series data), and ggeffects 1.5.2 (for lsmean calculations of explanatory variables).
Statistical model	Generalized Linear Model (GLM) (Error Distribution: Log-normal)
Explanatory variables applied in the full model	Year, season, and 8-directional sea current (categorical value as fixed effects) Water temperature, current speed, latitude of the northern edge of the Kuroshio in the fishing area, and latitudinal difference of the Kuroshio northern edge between longitudes (continuous value as first-order fixed effects)
Selection method of the final model	An exhaustive model search using AIC was conducted. From models within the range of the minimum AIC + 2, the one with the fewest number of explanatory variables and the highest effect from the aspect of marine environment and fishery was selected. It is noted that models that selects same variable at different depth layers obtained from FRA-ROMS II were excluded from the exhaustive model search.
Selected explanatory variables	Year, the water temperature at the 200 m depth layer, the latitude of the northern edge of the Kuroshio Current at the offshore area (138°E), and the latitude difference of the northern edge of Kuroshio between 138°E and139°E
Extraction method for annual trends	Extraction of the coefficients of year-fixed effects
Calculation method for confidence intervals	Bootstrap sampling of data with replacement, best model updates, and annual trend extraction were repeated 1,000 times.
Results of CPUE	Standardized CPUE remained almost flat up to 2017. However,

standardization	from 2018 onwards, it has continued to increase rapidly, with small fluctuations from year to year. In 2023, it shows an increase from the previous year and is the highest value during the analysis period. There were no significant differences observed between the trends of standardized CPUE and nominal CPUE. However, standardized CPUE was higher during 2002-2004, 2006, 2010-2012, 2014, and 2019, and nominal CPUE was higher during most of the other years.

1. Background

Information obtained from fisheries has been used for stock assessment because the information generally provides broader spatiotemporal coverage of stock distribution compared to research vessel surveys. On the other hand, the Catch Per Unit Effort (hereinafter, CPUE) derived from fisheries exhibits spatiotemporal bias in the effort and the marine environment may also affect fishing gear behavior, which may, in turn, affect catch efficiency. Standardization of CPUE through statistical methods is important to remove bias for an accurate assessment of stock status.

In the FY 2021 stock assessment for the Splendid Alfonsino of Pacific Japan, standardization using Generalized Linear Models (GLM) for CPUE in the Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures was attempted to develop more accurate tuning indices. We used “year”, “season”, “area” and “the distance to the Kuroshio axis” (near: 0-50 nautical miles, medium: 50-100 nautical miles, far: beyond 100 nautical miles) from major locations documented in the Quick Bulletin of Ocean Conditions provided by Hydrographic and Oceanographic Department of the Japan Coast Guard (categorical) as explanatory variables (all data collected by four prefectures were aggregated) for the GLM (Watari and Hanzawa 2022). The reason why distance to the Kuroshio current axis was implemented was to address concerns raisedby fisherman regarding the Kuroshio and its associated sea currents, which could impact catch efficiency and lead to a reduction in CPUE. However, the examined model could not be used as a tuning index of the stock caluculation because the effects of proximity to the Kuroshio could not be adequately eliminated, fishing styles, such as restrictions on fishing gear and the age structure of caught fish differed by area, and the model diagnostic results were not enough. In FY 2022, CPUE standardization models were separately developed for each district in light of these circumstances, with an attempt to consider introduce multiple variables for the explanatory variables considering the marine environment, adjusted to the scales (fishing grounds and entire habitat of the stock) (Watari et al., 2023). As a result, it was determined that the standardized CPUE of 6 areas among the 7 areas in the four Tokyo and three prefectures considered the influence of environmental factors more thoroughly, and since the model diagnostic results were generally acceptable, it was decided to introduce it as one of the tuning indices for the VPA (Standardized CPUE is still being examined for the Hachijojima Island Area). In 2023, to correspond to the “Expansion of standardized CPUE to areas of the ocean where it has not yet been implemented”, one of the topics identified for future consideration during the assessment of this stock, the standardized CPUE was examined using the data from the Omaezaki Area in Shizuoka Prefecture (Watari et al., 2024). As a result, the model diagnostic results were generally favorable, and changes in the CPUE caused by the effects of the Kuroshio and water temperature were corrected. Therefore, it was decided to use the yearly trend derived from this model as one of the tuning indices for the VPA of the Splendid Alfonsino of Pacific Japan.

This fiscal year, the standardization model for the Omaezaki Area of Shizuoka Prefecture was updated by adding the data of the latest year to the dataset of the previous fiscal years.

2. Method

2.1 Data

Monthly records of vertical long line fishing operations from the Omaezaki Area of Shizuoka Prefecture, where splendid alfonsino is caught, were used for the analysis. The data comprises monthly catch and number of landings (day・vessel) and does not include fishing operation location data. The standardization period was 2002-2023, and all records were used for the analysis.

2.2 Full Model

The developed standardization model is a GLM with log-normal error distribution (log-normal GLM). As mentioned above, marine environmental variables of different scales were used in the full model. As in previous fiscal years, the Kuroshio axis position information was utilized as a factor influencing the entire distribution area. The Kuroshio position information was derived from the Quick Bulletin of Ocean Conditions (https://www1.kaiho.mlit.go.jp/KANKYO/KAIYO/qboc/) by the Japan Coast Guard, and with the latitudes of the Kuroshio current northern edge (13 nautical miles from the axis) were extracted at 138°E, 139°E, 140°E, and 141°E (Lat_138, Lat_139, Lat_140, Lat_141). For the Omaezaki Area, the latitude of the Kuroshio northern edge at 138°E (Lat_138) was used as an explanatory variable to consider the position of the Kuroshio in the offshore area. Additionally, the latitudinal difference in the northern edge of the Kuroshio between longitudes (indicating the Kuroshio slope) was calculated for three longitudinal segments: 138°E-139°E, 139°E-140°E, and 140°E-141°E. These differences (Lat138_139, Lat139_140, and Lat140_141, respectively) were used as an indicators of “Kuroshio intrusion” to analyze how the Kuroshio current flow patterns, particularly large meanders, affect CPUE. These above variables associated with the Kuroshio were integrated into the model as first-order continuous variables.

Reanalysis data for water temperature, current direction, and current speed at 0 m, 100 m, 200 m, and 400 m depth, and the bottom layer were obtained from FRA-ROMS II (Kuroda et al., 2017, data accessed April 4, 2024) to consider the effect of the marine environment on each fishing ground. Representative fishing grounds consisting of 0.1° grid units of latitude and longitude were delineated after consultation with organizations participating in the stock assessment, and the reanalysis data extracted at those fishing grounds were used as representative values of the marine environment for that fishing ground. For the Omaezaki Area, grids 51-54 in Fig. 1 were selected as fishing grounds for analysis. FRA-ROMS II daily reanalysis data at each grid were averaged to obtain monthly average. The monthly values of water temperature and current speed were used as first-order continuous variables, while the current direction was converted to 8-direction categorical variables (Direcfct) after monthly averaging. For current direction and current speed, the respective daily data were converted to two dimensional vectors before averaging, and then reconverted to current direction and current speed.

Continuous variables were treated as first-order effects because no non-linearity was detected between environmental variables and nominal CPUE (Fig. 2), and this approach facilitated interpretation of the effects of environmental variables on the CPUE.

Year effects and seasonal effects (Quarter: dividing 12 months into four periods - Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) were treated as categorical effects, and the full model was constructed by using each variable as a fixed effect. The full model is as follows.

log(CPUE) ~ Year + Quarter +
Temperature_0 + Temperature_100 + Temperature_200 + Temperature_400 +
Temperature_Bottom +
Speed_0 + Speed_100 + Speed_200 + Speed_400 + Speed_Bottom +
Direcfct_0 + Direcfct_100 + Direcfct_200 + Direcfct_400 + Direcfct_Bottom +
Lat_138 +
Lat138_139 + Lat139_140 + Lat140_141

The correlations between marine environmental variables are presented in Fig. 3. Since the number of estimated parameters would exceed the number of data if interactions between various variables were considered and could make interpretation complex, the standardization model for this stock was restricted to main effects under the situation that only monthly CPUE data are currently available.. The collection and organization of more detailed data such as record by daily and each fishing operation would be beneficial for future analyses..

2.3 Model Selection

The best model was determined through Akaike’s Information Criterion (AIC)-based model selection using an explanatory variable exhaustive search for the above full model, and then select the model with minimum degrees of freedom of the parameters among those within the minimum AIC + 2 range with the consideration of explanatory power in terms of environment and fishery. Note that, in the first step of the AIC variable selection, models including explanatory variables from multiple depth layers obrained from FRA-ROMS II (e.g., models including both 0 m and 100 m water temperatures) were preliminarily excluded from candidate models in consideration of interpretational simplicity and effects of overfitting. The best model was selected from the model candidates containing only one depth layer.

2.4 Model Diagnostics

As the standardization model for this stock is a log-normal GLM, the normality and homoscedasticity of residuals were tested for the best model using the QQ plot, histogram of residuals, and stratified deviance residuals by depth calculated for each explanatory variable.

2.5 Extraction of Annual Trends

The intercept value and the coefficient of the year effect were extracted from the best model. The intercept value was set as the standardized CPUE for the initial year of the analysis period, and the intercept value plus the coefficient of the year effect were set for the standardized CPUE of subsequent years.

2.6 Calculation of Confidence Intervals

The process of updating the parameters in the best model and calculating annual trends was repeated 1,000 times using bootstrap sampling with replacement to derive 95% confidence intervals from the results.

3 Results and Consideration

3.1 Analysis Results for This Year

Based on the above model selection criterion, the following model was selected as the best model (Table 1).

log(CPUE) ~ Year + Temperature_200 + Lat_138 + Lat138_139

For the Omaezaki Area, as a result of the model selection process using an exhaustive search based on AIC, 26 models were within the minimum AIC+2 range after excluding models with multiple depth layers selected for the same explanatory variable obtained from FRA-ROMS II. Among these, the model exhibiting the minimum degrees of freedom of the parameters was selected as the best model. Other models within the minimum AIC+2 range suggested that, in addition to the explanatory variables of selected in the best model, many models also included indices of Kuroshio intrusion and current speed east of 139°E, indicating that explanatory variables associated with the influence of the Kuroshio intrusion, flow within the fishing grounds and water temperature tend to be selected as effective variable in many cases. The CPUE responses to each of the selected explanatory variables in the best model (Fig. 4) also detected changes in the CPUE caused by fluctuations in the strength of Kuroshio position and intrusion, and water temperature.

The QQ plot for the best model indicated that the deviance residuals and their expected values did not differ significantly, and there were no major problems with the normality of residuals (Fig. 5). There was also no significant bias in the deviance residuals across variable hierarchies for any of the models (Fig. 6).

Variations in the standardized CPUE estimated by the best model and nominal CPUE derived from annual and monthly catch and number of landings are presented in Fig. 7 and Table 2. Standardized CPUE remained almost flat up to 2017. However, from 2018 onwards, it has continued to increase rapidly, with small fluctuations from year to year. In 2023, the value increased from the previous year, reaching the highest level during the analysis period. There were no significant differences observed between the trends of standardized CPUE and nominal CPUE. However, standardized CPUE was higher during 2002-2004, 2006, 2010-2012, 2014, and 2019, and nominal CPUE was higher during most of the other years.

3.2 Comparison with the Previous Fiscal Year’s Results

The explanatory variables selected for this fiscal year’s best model were the same as those of the previous fiscal year, and there were no significant differences from the previous year in the standardized CPUE trends derived from the best model.

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Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2023) FY 2022 Stock Assessment of the Splendid Alfonsino of Pacific Japan. FRA-SA2022-AC-37, FY 2022 Fisheries Stock Assessment in the Waters Around Japan, Japan Fisheries Research and Education Society, Fisheries Agency, Tokyo, 50 pp. https://abchan.fra.go.jp/wpt/wp-content/uploads/2023/06/details_2022_37.pdf

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Table 1. Model selection results: Presenting models within the minimum AIC+2 range, excluding models containing multiple-depth layers explanatory variables from FRA-ROMS II. The yellow-highlighted row represents the best model.

Depth	Flow direction					Kuroshio northern edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Sea-son	Year	df	logLik	AIC	delta
	0	100	200	400	Bottom	138°E	138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom						
12.16						-0.25	0.25	0.10	0.08								0.08				+	28	-75.0	206.1	0.0
8.91						-0.16	0.17										0.08				+	26	-77.0	206.1	0.0
8.28						-0.14	0.16					-0.31					0.09				+	27	-76.3	206.6	0.5
10.07						-0.19	0.19	0.05									0.08				+	27	-76.3	206.6	0.6
8.21						-0.14	0.16				-0.25						0.09				+	27	-76.3	206.7	0.6
8.26						-0.14	0.15					-0.39						0.15			+	27	-76.4	206.8	0.7
11.47						-0.23	0.24	0.09	0.07			-0.28					0.09				+	29	-74.4	206.9	0.8
11.42						-0.23	0.24	0.10	0.07		-0.23						0.09				+	29	-74.5	206.9	0.8
9.09						-0.16	0.16											0.12			+	26	-77.5	207.0	0.9
8.58						-0.15	0.16						-0.39				0.09				+	27	-76.5	207.0	0.9
8.22						-0.14	0.15				-0.31							0.15			+	27	-76.5	207.0	1.0
9.43						-0.17	0.18	0.05				-0.31					0.09				+	28	-75.6	207.2	1.1
9.37						-0.17	0.18	0.05			-0.25						0.09				+	28	-75.6	207.2	1.1
11.76						-0.24	0.24	0.10	0.07				-0.34				0.09				+	29	-74.6	207.2	1.2
8.65						-0.15	0.15						-0.48					0.14			+	27	-76.7	207.4	1.3
11.68						-0.24	0.25	0.10	0.08	-0.13							0.09				+	29	-74.7	207.4	1.4
8.44						-0.15	0.16			-0.13							0.09				+	27	-76.7	207.4	1.4
9.41						-0.17	0.18		0.03								0.09				+	27	-76.7	207.5	1.4
9.74						-0.18	0.18	0.06					-0.40				0.08				+	28	-75.8	207.5	1.4
8.37						-0.14	0.15			-0.19								0.14			+	27	-76.9	207.7	1.6
12.05						-0.24	0.23	0.08	0.08									0.12			+	28	-75.9	207.7	1.6
9.60						-0.18	0.19	0.06		-0.15							0.09				+	28	-75.9	207.8	1.8
12.20						-0.25	0.25	0.10	0.08					0.19			0.08				+	29	-75.0	208.0	1.9
11.09						-0.22	0.22	0.08	0.07			-0.35						0.14			+	29	-75.0	208.0	1.9
8.92						-0.16	0.17							0.10			0.08				+	27	-77.0	208.1	2.0
9.13						-0.16	0.17	0.04				-0.38						0.14			+	28	-76.0	208.1	2.0

Table 2. Standardized and nominal CPUE: CPUE values normalized using the mean value over the analysis period.

Year	Nominal CPUE (Normalization)	Standardized CPUE (Normalization)	CI_Lower limit	CI_Upper limit	CV
2002	0.72	0.87	0.75	1.00	0.08
2003	0.75	0.87	0.71	1.04	0.10
2004	0.72	0.83	0.69	0.99	0.09
2005	1.19	0.98	0.74	1.42	0.17
2006	0.80	0.89	0.71	1.20	0.14
2007	0.79	0.73	0.60	0.90	0.10
2008	0.62	0.62	0.52	0.74	0.09
2009	0.62	0.62	0.50	0.74	0.10
2010	0.64	0.73	0.58	0.90	0.12
2011	0.69	0.79	0.66	0.94	0.09
2012	0.86	0.92	0.76	1.08	0.09
2013	0.87	0.82	0.66	0.99	0.10
2014	1.05	1.14	0.97	1.33	0.08
2015	0.84	0.79	0.61	0.98	0.12
2016	0.90	0.88	0.74	1.04	0.09
2017	0.99	0.88	0.68	1.10	0.12
2018	1.12	1.02	0.78	1.29	0.13
2019	1.35	1.44	1.24	1.62	0.07
2020	1.46	1.41	1.22	1.63	0.08
2021	1.59	1.57	1.32	1.84	0.09
2022	1.70	1.53	1.17	1.96	0.13
2023	1.72	1.66	1.36	1.98	0.10

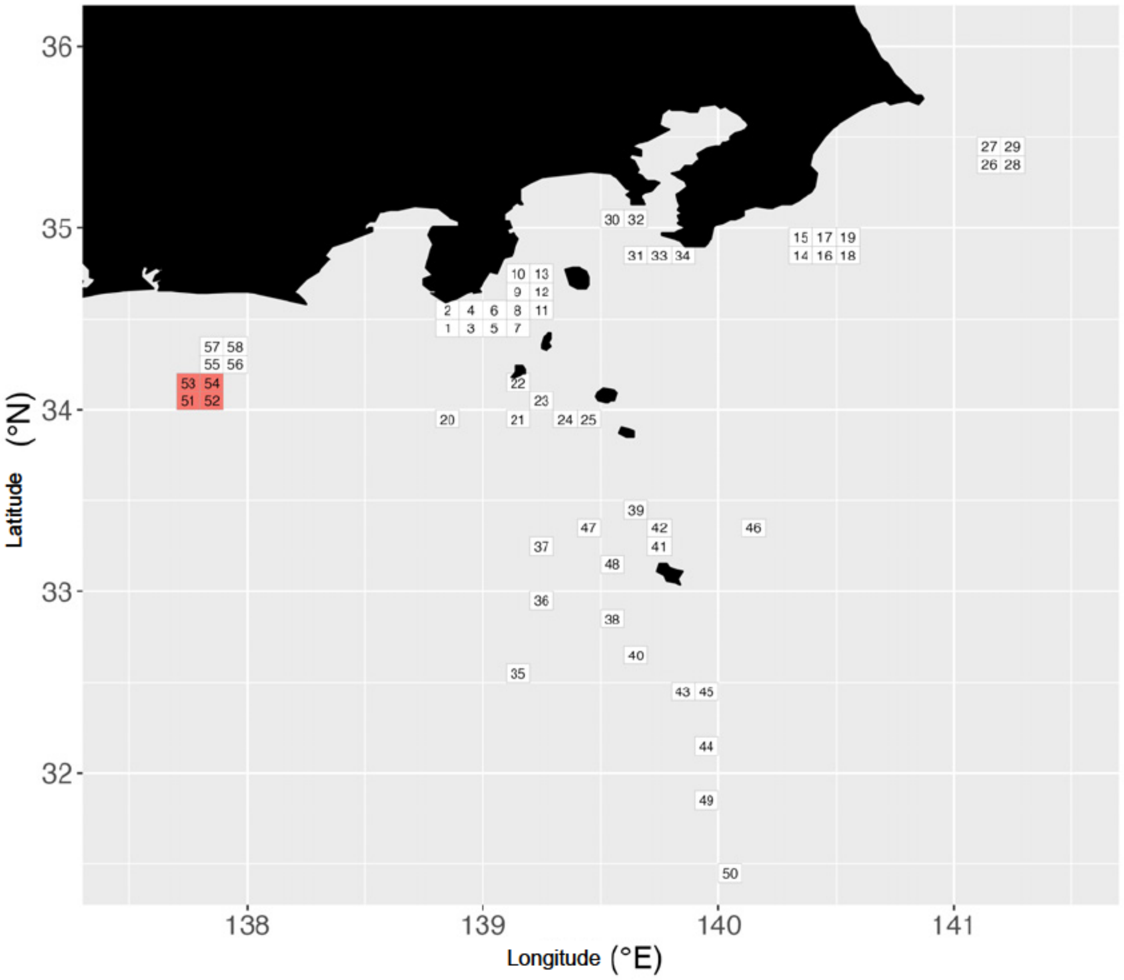

Fig. 1. Fishing ground for each area used for extracting FRA-ROMS II reanalysis values - Data extracted for 0.1° grid units of latitude and longitude

For the Omaezaki Area, grids 51-54 were used.

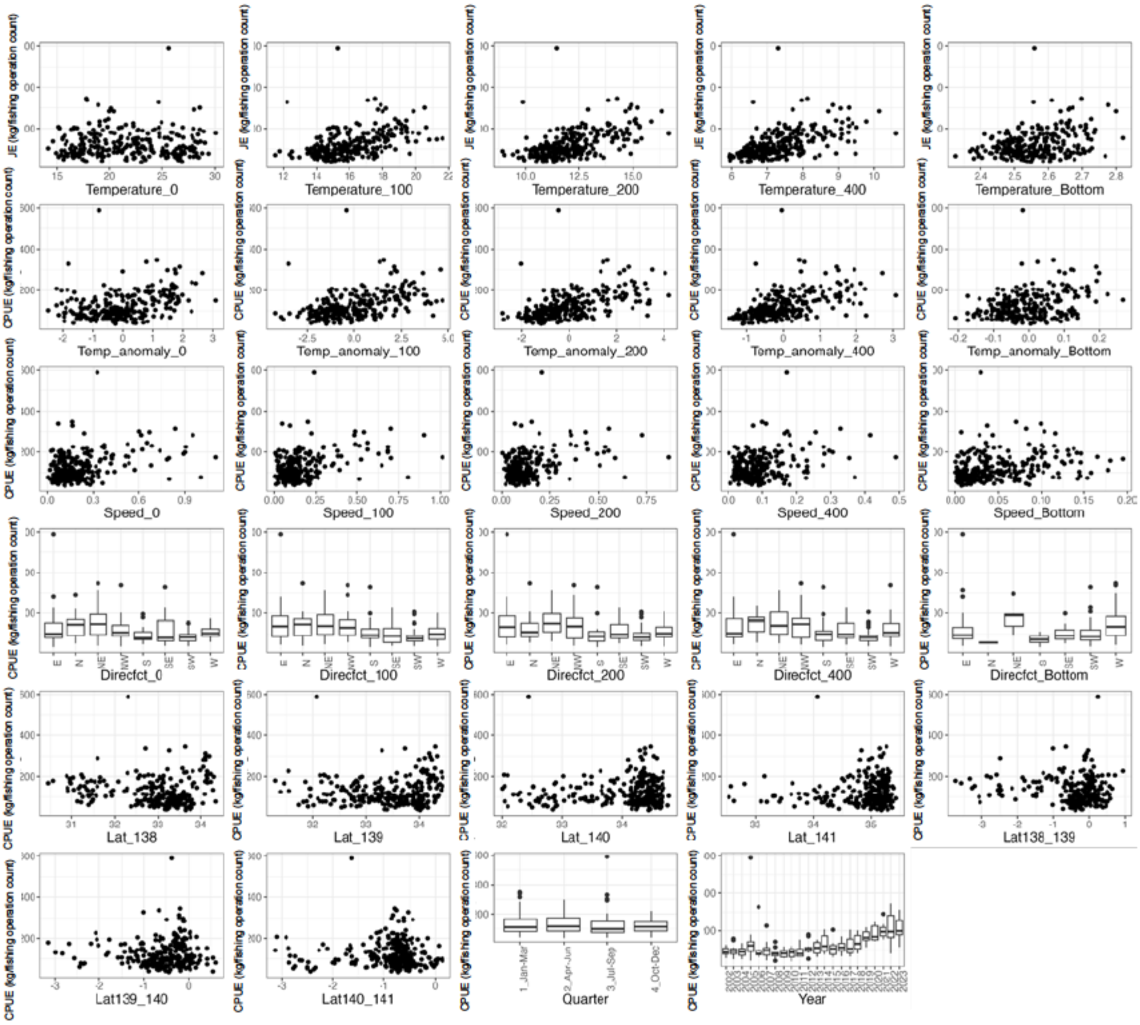

Fig. 2. Relationship between the explanatory variables introduced into the standardization model and nominal CPUE

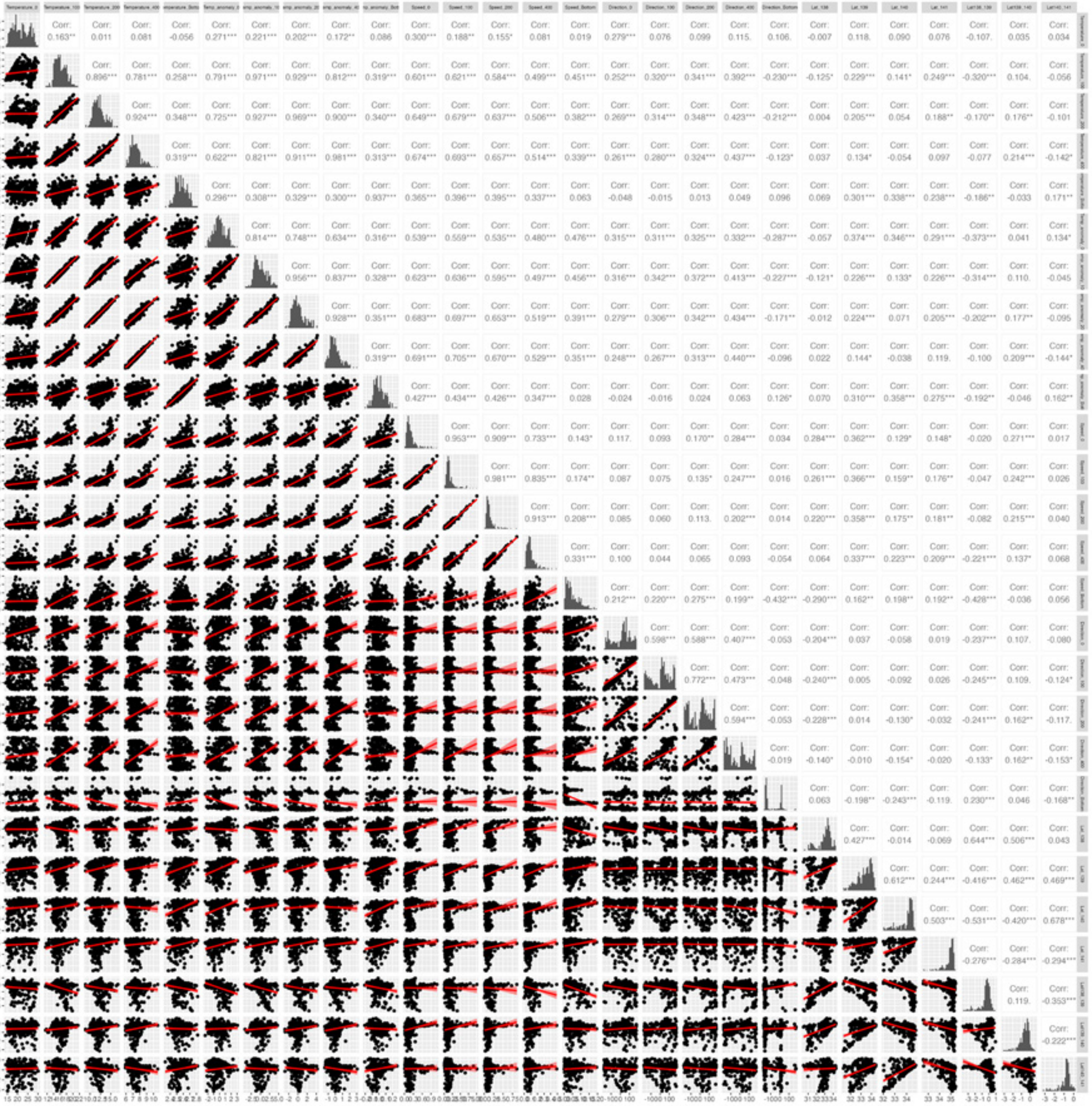

Fig. 3. Correlation between the marine environmental data used in the standardization model

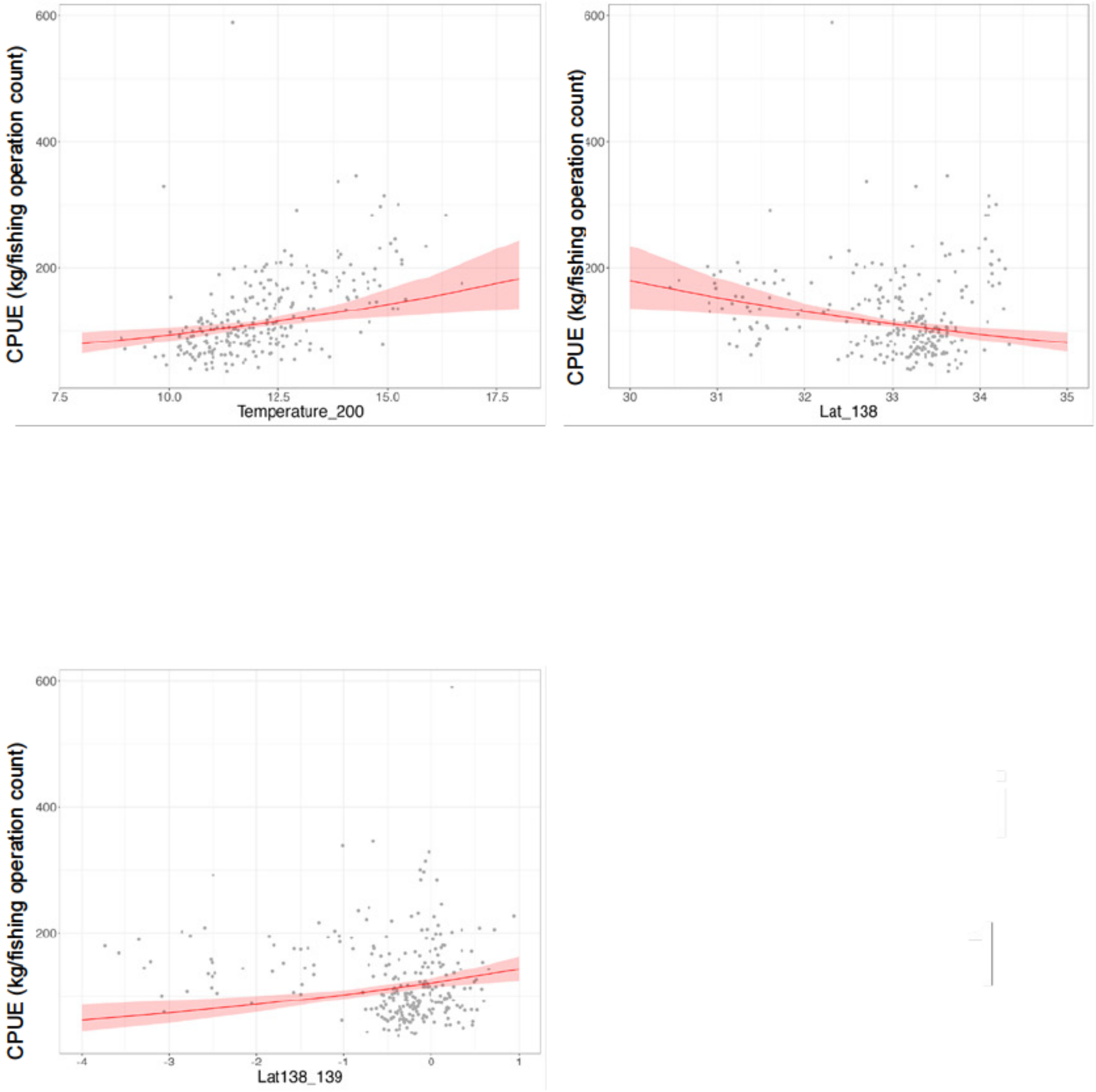

Fig. 4. Partial effects of each explanatory variable in the best model, with the red band and red whiskers representing the 95% confidence interval

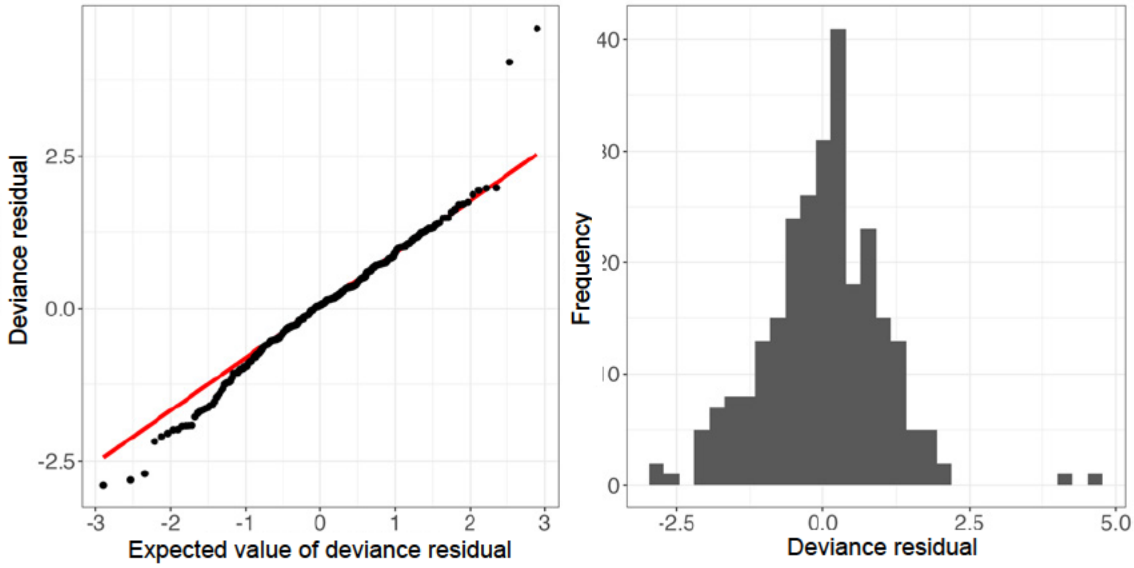

Fig. 5. QQ plot (left) and frequency distribution of residuals (right) in the best model

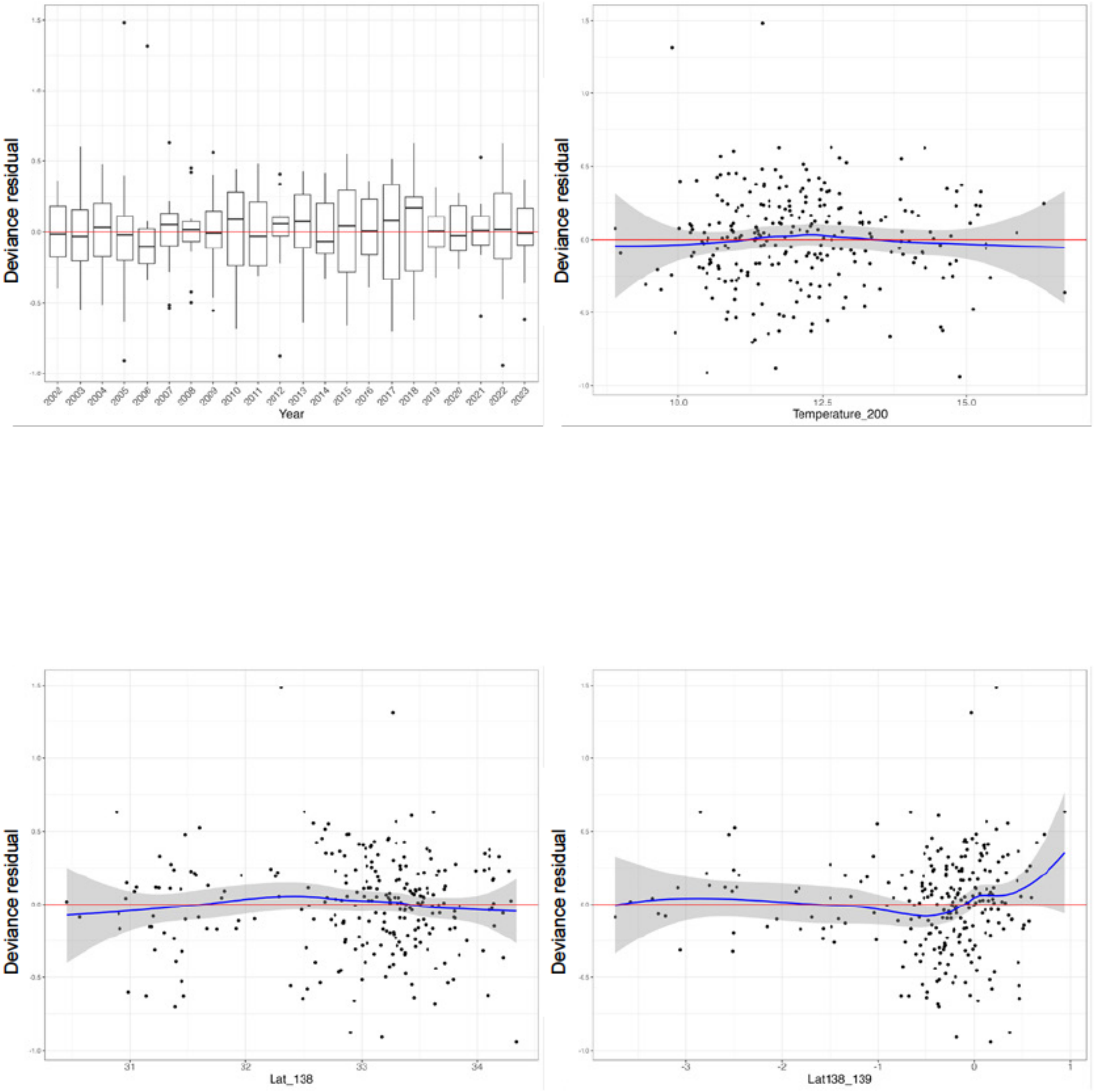

Fig. 6. Stratified deviance residuals in the best model: the blue line and gray band in the residual plots for Temperature_200, Lat_138, and Lat138_139 represent fitted smoothing curves (loess) and their 95% confidence intervals.

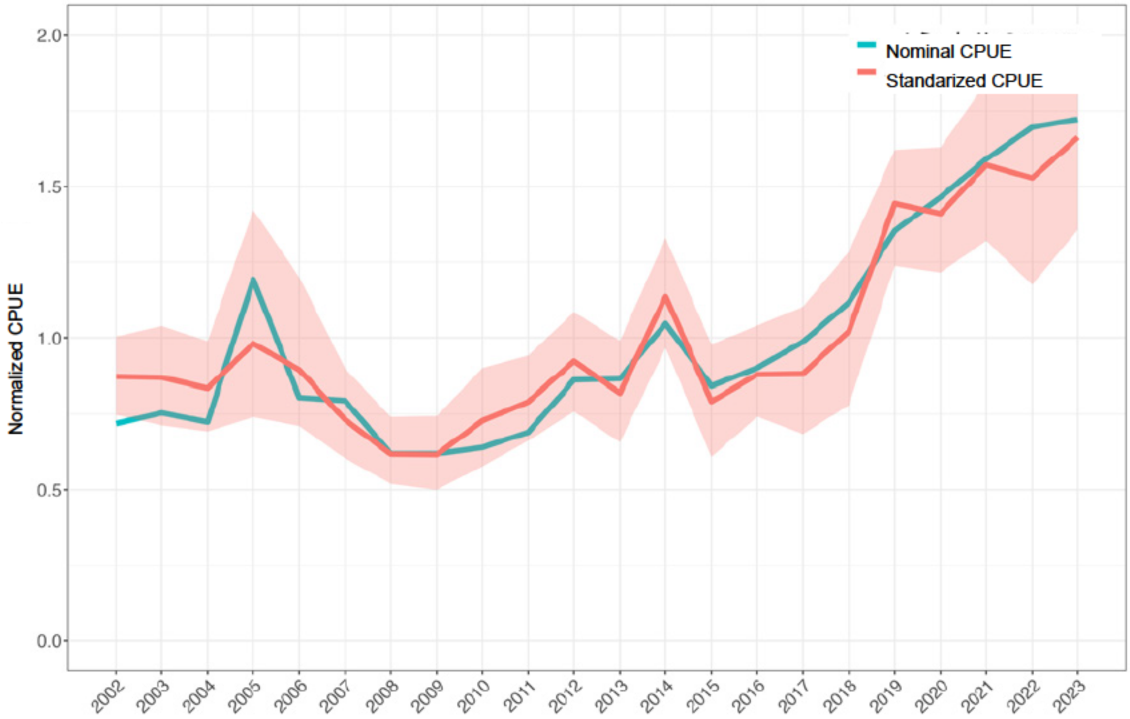

Fig. 7. Transition of standardized and nominal CPUE (CPUE values normalized by the mean value over the analysis period)

The red band represents the 95% confidence interval obtained from 1,000 iterations of bootstrap sampling of the data and yearly trend estimation with the best model.

Summary of the estimated parameters of the best model
glm (formula = log(CPUE) ~ Lat_138 + Lat138_139 + Temperature_200 + Year + 1, family = gaussian, data = dat3)

	Estimate	Standard Error	z value	Pr(>|z|)	
(Intercept)	8.915	1.636	5.448	0.0000	***
Lat_138	-0.159	0.047	-3.409	0.0008	***
Lat138_139	0.165	0.046	3.588	0.0004	***
Temperature_200	0.083	0.025	3.270	0.0012	**
Year2003	-0.003	0.139	-0.025	0.9804	
Year2004	-0.045	0.144	-0.310	0.7565	
Year2005	0.117	0.148	0.791	0.4298	
Year2006	0.025	0.143	0.178	0.8591	
Year2007	-0.176	0.145	-1.212	0.2268	
Year2008	-0.345	0.144	-2.394	0.0174	*
Year2009	-0.348	0.146	-2.380	0.0181	*
Year2010	-0.181	0.140	-1.292	0.1978	
Year2011	-0.099	0.140	-0.704	0.4819	
Year2012	0.056	0.141	0.400	0.6898	
Year2013	-0.063	0.146	-0.435	0.6642	
Year2014	0.265	0.142	1.868	0.0630	.
Year2015	-0.097	0.146	-0.664	0.5072	
Year2016	0.008	0.145	0.054	0.9570	
Year2017	0.011	0.151	0.072	0.9426	
Year2018	0.158	0.162	0.976	0.3301	
Year2019	0.504	0.158	3.199	0.0016	**
Year2020	0.481	0.160	3.010	0.0029	**
Year2021	0.589	0.159	3.702	0.0003	***
Year2022	0.561	0.163	3.433	0.0007	***
Year2023	0.646	0.165	3.917	0.0001	***

	Estimate	Standard Error	z value	Pr(>|z|)

*Signif. codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05*

(Dispersion parameter for Gaussian family taken to be 0.115932)

Null deviance: 59.39 on 263 degrees of freedom

Residual deviance: 27.71 on 239 degrees of freedom

AIC: 206.08

Supplementary Table. Explanatory variables and corresponding abbreviations

Variable name		Variable abbreviation
Year		Year
Season		Quarter
Water temperature	0 m	Temperature_0
	100 m	Temperature_100
	200 m	Temperature_200
	400 m	Temperature_400
	Bottom layer	Temperature_Bottom
Current speed	0 m	Speed_0
	100 m	Speed_100
	200 m	Speed_200
	400 m	Speed_400
	Bottom layer	Speed_Bottom
Flow direction (continuous)	0 m	Direction_0
	100 m	Direction_100
	200 m	Direction_200
	400 m	Direction_400
	Bottom layer	Direction_Bottom
Flow direction (category)	0 m	Direcfct_0
	100 m	Direcfct_100
	200 m	Direcfct_200
	400 m	Direcfct_400
	Bottom layer	Direcfct_Bottom
Latitude of the Kuroshio northern edge in the offshore area	138E	Lat_138
	139E	Lat_139
	140E	Lat_140
	141E	Lat_141
Latitudinal difference of the Kuroshio northern edge between longitudes	138°E-139°E	Lat138_139
	139°E-140°E	Lar139_140
	140°E-141°E	Lat140_141