Standardized CPUE for Pacific Bluefin tuna caught by Japanese coastal and offshore longline in 2022 update assessment

Yohei Tsukahara, Hiromu Fukuda and Shuya Nakatsuka

Highly Migratory Resources Division, Fisheries Resources Institute,
Japan Fisheries Research and Education Agency
2-12-4, Fukuura, Kanazawa-ku, Yokohama, Kanagawa 236-8648, JAPAN

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Summary

The standardized CPUE up to one year before the stock assessment was usually used for the PBF assessment. On the other hand, the Japanese longline fishery has introduced the management by individual quota (IQ) system since 2021, i.e., 2020 fishing year in the assessment model. The introduction of IQ generally alters the fishing strategy, resulting in the change of fishing efficiency (q). The ISC PBFWG had discussed the availability of the data in 2021 and generally agreed to use the standardized CPUE as an abundance index up to 2019 fishing year for the 2022 stock assessment in one-day meeting on January 28, 2022.

This document presents the results of the standardized CPUE up to 2019 fishing year on Japanese longline fishery for PBF, which will be used as an abundance index in 2022 update assessment. A predicted index showed consistent trajectory with that for the previous assessment and continuously increase since 2011 fishing year.

Introduction

The spatiotemporal generalized linear mixed model (spatiotemporal GLMM) incorporating fine spatial and temporal structures as random effects is one of the advanced and useful tools (Thorson et al., 2015 a, b). The spatiotemporal model enables us to predict spatial variation across multiple location, time intervals, for multiple categories such as size, age and sex. The spatiotemporal model is widely used in the CPUE standardization for highly migratory species recently. The time series of CPUE on Japanese coastal longline fishery (JPLL), which was standardized by generalized spatiotemporal GLMM, had been used as an abundance index for large sized Pacific Bluefin Tuna (PBF) mostly corresponding to size of spawning stock biomass (SSB) since 2020 stock assessment (Tsukahara et al 2020, ISC 2020).

The standardized CPUE up to one year before the stock assessment was usually used for the PBF assessment. On the other hand, the Japanese longline fishery has introduced the management by individual quota (IQ) system since 2021 to allow each fisherman to have balanced opportunity to catch PBFs. The introduction of IQ generally alters the fishing strategy, resulting in the change of fishing efficiency (q). The ISC PBFWG had investigated the influence of IQ system on the fishery and discussed the availability of the data in 2021. More than 75 percent of vessels kept some unused quota at the end of June, which is the end of analysis period. The only around 50% of quota in total for this fishery was consumed at the end of June, while the quota had been exhausted by that time until 2020. As the longline fishery ultimately had consumed the quota within the year 2021, the operations during the analysis period should be considered to be subject to the different fishing strategy, resulting in different fishing efficiency from those in previous years. Therefore, the PBFWG decided to use the standardized CPUE as an abundance index up to 2020, which is 2019 fishing year in the assessment model, in one-day meeting on January 28, 2022.

This document presents the results and diagnostics of the standardization by spatiotemporal GLMM up to 2019 FY, which will be used as an abundance index in 2022 PBF assessment. The assessment will be update assessment from that in 2020. Therefore, the procedure of the standardization is basically same as that for the previous index for 2020 assessment model except for the data filtering regarding the fish size (Tsukahara et al 2021).

Materials and Methods

Data collection and filtering for CPUE standardization

The fishery operational data by JPLL, which is called logbook data hereafter, has been collected by Japan Fishery Agency and compiled by Japan Fisheries Research and Education Agency since 1994. The logbook data contains individual records of fishing operation: date (year, month and day) and location (latitude and longitude) of longline set, total number of hooks per set, number of hooks per basket (HPB), catch in number and cumulative catch in weight by various fish species including PBF. Some data in the logbook could be regarded as irrelevant operations and misreporting for PBF. To remove such data, data filtering was conducted by removing data under the following criteria: (1) vessel size more than 20 gross register tonnages (GRT), (2) season other than April to June, (3) the catch in number more than 50 per a cruise, (4) number of hooks less than 1,000, (5) HPB less than 9 or more than 24, (6) the locations where PBF was not caught over 5 years through the data period from 1994 to 2020 (Fig. 1), (7) locations in the south of 23-degree north latitude, north of 35-degree of north latitude, west of 124-degree east longitude or east of 145-degree east longitude (Fig. 1), and (8) suspension and buffer period for the time of fishery suspension.

In terms of the longline fishery management in Japan, the fishery specific catch quota for the large PBF (30 kg and larger) has been implemented since 2018 calendar year (WCPFC-NC 2019) to comply with the conservation and management measure (WCPFC CMM 2018-02) adopted by the Western and Central Pacific Fisheries Commission (WCPFC). The catch quota was allocated from the national government to the longline fishery association and the association has managed their quota under the supports of the government. Since 2017 FY, the most of JPLL was required to suspend their landings of PBF in the middle of fishing season of each year because their catch amount almost reached their allocated quota. In 2018 FY, they resumed the landings after suspension towards the main fishing season in accordance with the additional quota from the reservation quota of the government. In 2019 FY, a modification to the management for JPLL, which recognized larger amount of allocation to the JPLL fishery with management by monthly quota, was applied to increase the number of operations for PBF from April to June. This was expected to reduce the negative influence on this abundance index by suspension, although the landings at the turn of the month likely to be subject to the effects of monthly quota management, which could be regarded as buffer periods of management. Further research on the practical information on quota management is needed for this area. In this document, therefore, the data during suspended and buffer periods was removed from this analysis, which were from 21st May in 2017 FY, from 11th May to 19th June in 2018 FY and from 21st April to 30th April, from 11th May to 31st May, from 11th June and first three days in each month in 2019 FY.

In addition to these filters for the previous model, an additional filtering regarding the fish size is applied for this standardization so that the smaller sized fish which was rarely caught by this fishery before 2018 FY was excluded from the dataset (Tsukahara et. al. 2021). The average weight, i.e. total weight in catch over total number in catch, in one operation was used as the threshold of small sized fish. When the average weight is less than 60kg, which corresponds to the 5% selection in this fishery based on the selectivity estimated in the 2020 assessment, the catch record was removed while effort data remained. This filtering keeps the representative range of size by this index being consistent by reducing the impact of the difference of abundance by age on the increase and/or decrease of index. The PBFWG have considered that this additional filter is a reasonable short-term solution (ISC 2021).

Spatiotemporal model

The filtered set-by-set logbook data including catch in number and fishing effort, number of hooks, were aggregated by spatial stratum (i.e., 1 x 1 degrees) and temporal strata (i.e., year and season) to improve the estimation efficacy of spatiotemporal model. The seasonal stratum, Day 10, was defined as intervals of every 10 days from April 1 to June 30 except for the end of May, only which have 11 days. The spatiotemporal modelling package, the Vector Autoregressive Spatio-Temporal (VAST) package, is currently available as an R-package (Thorson, 2019). However, the VAST was not directly used in this study. Instead of using the VAST, the original C++ codes of VAST were modified to conduct flexible modeling and R-package "TMB" (version 1.7.15) was used for the optimization of the model mainly to incorporate seasonal effects (Day 10) into spatiotemporal model. For PBF spatiotemporal model, one step model only by catchability was used to predict an abundance index as in the case of blue shark standardization (Kai et al, 2017). Since the catch number of PBF is count data which has overdispersion even after data filtering and aggregation by spatial and temporal strata, the negative binomial model (NB) were used as the observation models. Catch in number was used as a response variable. The models selected in last update based on the AIC have main effects of Year, t, Day10, d, Site, s, and three-dimensional interaction term between Year and Site day10, with offset terms by Hooks, h.

$$p(i) = \beta(t_i) + \xi(d_i) + \delta(s_i) + \upsilon(t_i, s_i, d_i) + h_i \quad \text{(Eq. 1)}$$

where β, ξ,δ,υ is the inference of main effects of Year, Day10, Site and interaction of Year and Site. Only year effect, β, was treated as fixed effects and the other effects including interactions were treated as random effects which have correlation structure, either Gaussian Markov Random Field for site effects or one-dimension auto-regression for Year, Day10 effects.

Results

The update index showed the consistent trajectory with previous one (Fig. 3). Since 1993 FY, index gradually decreased, while there was a substantial peak around 2004 FY. The index in 2011 FY was the lowest and then it showed continuous increase trend to the present. The spatial distribution of abundance over year was shown in Fig. 3. There was high abundance area widely up until early 2000's. After that, high abundance area was gradually shrunk toward South-west area around Nansei spawning ground corresponding to the decrease of annual abundance index. On the other hand, the high abundance area was expanded broadly again in most recent year.

Randomized quantile residual (RQR) was used for the diagnostics (Dunn and Smyth 1995). NB models where residuals are far from normality, aligning nearly parallel curves according to distinct response values, which makes it difficult to conduct visual inspections (Kai et al. 2019). Figure 4 showed the diagnostic plots by RQR. QQ plots showed somewhat skewed at the both edges, but there were no considerable negative signals in residual distributions and QQ-plot. Additionally, main parameters, directly related to each effect, have enough small final gradient and far from boundaries and initial values (Table 2). These indicate that the CPUE on Japanese longline fishery was appropriately standardized by the spatiotemporal GLMM.

Conclusion

The CPUE on the Japanese longline fishery was standardized by spatiotemporal GLMM in basically same manner as previous standardization except for an additional filtering regarding the fish size in catch. The standardized CPUE up to 2019 FY showed consistent trajectory with that for the previous assessment and continuously increase since 2011 FY. There were no considerable negative signals in the diagnostics. Therefore this standardized CPUE can be considered to be appropriate for an abundance index in the 2022 update assessment.

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Table 1 Annual catch in number, the number of longline operations and nominal CPUE in logbook data from April to June and predicted CPUE by spatiotemporal GLMM.

		Data in Logbook						Predicted abundance index	
		Catch in number			Effort (x1000 hooks)		Nominal CPUE w/o suspension and less 60kg	Relative Abundance index	CV
Calendar Year	Fishing Year	All	w/o suspension	w/o suspension and less60kg	All	w/o suspension			
1994	1993	2707	2707	2687	5155	5155	0.521	2.29	0.08
1995	1994	1595	1595	1574	4755	4755	0.331	1.67	0.08
1996	1995	2501	2501	2471	5220	5220	0.473	2.03	0.07
1997	1996	2629	2629	2589	5686	5686	0.455	2.09	0.06
1998	1997	3109	3109	3097	6684	6684	0.463	1.93	0.06
1999	1998	3830	3830	3823	9665	9665	0.396	1.49	0.05
2000	1999	2304	2304	2299	8787	8787	0.262	1.06	0.06
2001	2000	1813	1813	1813	9584	9584	0.189	0.77	0.06
2002	2001	2109	2109	2094	9762	9762	0.214	0.92	0.06
2003	2002	2622	2622	2618	8805	8805	0.297	1.40	0.05
2004	2003	3644	3644	3634	10196	10196	0.356	1.50	0.04
2005	2004	3830	3830	3783	9747	9747	0.388	1.53	0.04
2006	2005	1992	1992	1981	9434	9434	0.210	0.88	0.05
2007	2006	2976	2976	2953	9011	9011	0.328	0.96	0.05
2008	2007	1471	1471	1454	9292	9292	0.156	0.60	0.06
2009	2008	1280	1280	1251	10936	10936	0.114	0.35	0.07
2010	2009	709	709	686	9025	9025	0.076	0.22	0.09
2011	2010	496	496	442	8873	8873	0.050	0.18	0.09
2012	2011	369	369	360	9455	9455	0.038	0.14	0.09
2013	2012	738	738	735	9507	9507	0.077	0.30	0.07
2014	2013	681	681	670	8543	8543	0.078	0.30	0.08
2015	2014	511	511	507	6773	6773	0.075	0.38	0.08
2016	2015	631	631	607	5710	5710	0.106	0.40	0.09
2017	2016	1190	1190	1160	8014	8014	0.145	0.65	0.07
2018	2017	506	407	381	4999	2729	0.140	0.66	0.14
2019	2018	1287	1183	1159	7531	5492	0.211	0.90	0.09
2020	2019	1934	1042	773	6215	2644	0.292	1.38	0.14

Table 2. Initial and final condition of each parameter related to explanatory variables. ρ is the autocorrelation parameter for Day10 and Year. The beta means fixed terms of Year effects.

Parameter	Starting value	Lower boundary	Maximum likelihood estimation	Upper boundary	Final gradient
ρ (Year)	0	-Inf	0.773	Inf	4.1E-04
ρ (Day10)	0	-Inf	0.685	Inf	2.0E-03
beta_1994	-5	-Inf	-8.913	Inf	1.9E-04
beta_1995	-5	-Inf	-9.244	Inf	-4.7E-05
beta_1996	-5	-Inf	-9.027	Inf	3.1E-04
beta_1997	-5	-Inf	-8.997	Inf	-2.7E-04
beta_1998	-5	-Inf	-9.104	Inf	1.5E-04
beta_1999	-5	-Inf	-9.455	Inf	-1.7E-04
beta_2000	-5	-Inf	-9.705	Inf	-1.9E-04
beta_2001	-5	-Inf	-10.015	Inf	1.9E-04
beta_2002	-5	-Inf	-9.834	Inf	-2.1E-04
beta_2003	-5	-Inf	-9.465	Inf	1.7E-04
beta_2004	-5	-Inf	-9.384	Inf	3.1E-04
beta_2005	-5	-Inf	-9.344	Inf	-1.4E-04
beta_2006	-5	-Inf	-9.892	Inf	1.8E-04
beta_2007	-5	-Inf	-9.820	Inf	6.5E-06
beta_2008	-5	-Inf	-10.217	Inf	-4.6E-05
beta_2009	-5	-Inf	-10.832	Inf	3.2E-05
beta_2010	-5	-Inf	-11.302	Inf	7.8E-05
beta_2011	-5	-Inf	-11.525	Inf	3.2E-05
beta_2012	-5	-Inf	-11.696	Inf	-1.7E-05
beta_2013	-5	-Inf	-10.945	Inf	2.9E-05
beta_2014	-5	-Inf	-10.905	Inf	-7.1E-05
beta_2015	-5	-Inf	-10.677	Inf	3.4E-06
beta_2016	-5	-Inf	-10.634	Inf	-1.3E-04
beta_2017	-5	-Inf	-10.176	Inf	6.9E-05
beta_2018	-5	-Inf	-10.162	Inf	2.8E-04
beta_2019	-5	-Inf	-9.891	Inf	2.1E-05
beta_2020	-5	-Inf	-9.470	Inf	-1.8E-04

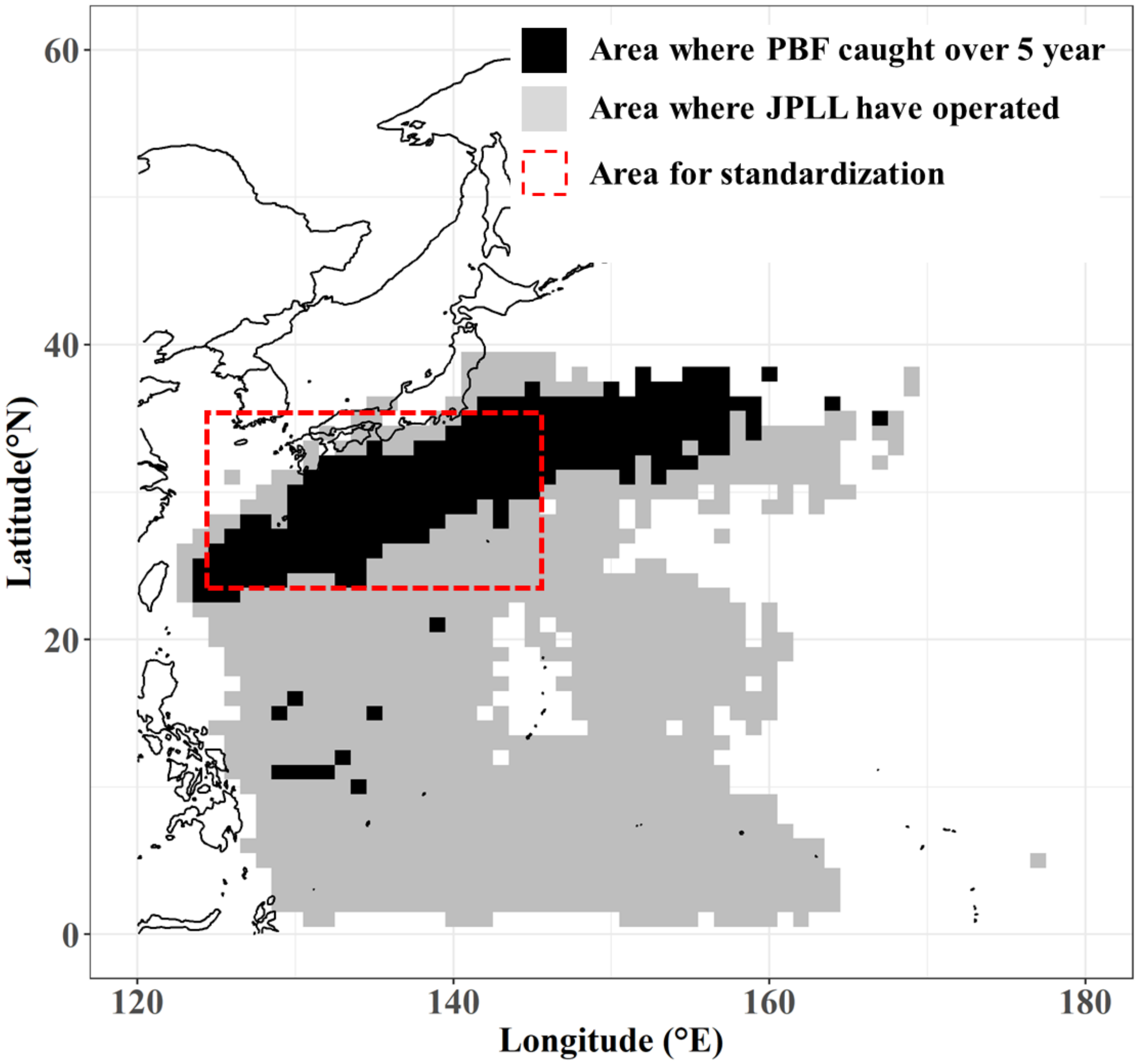

Figure 1. The spatial distribution of operation by Japanese coastal longline from 1994 to 2019.

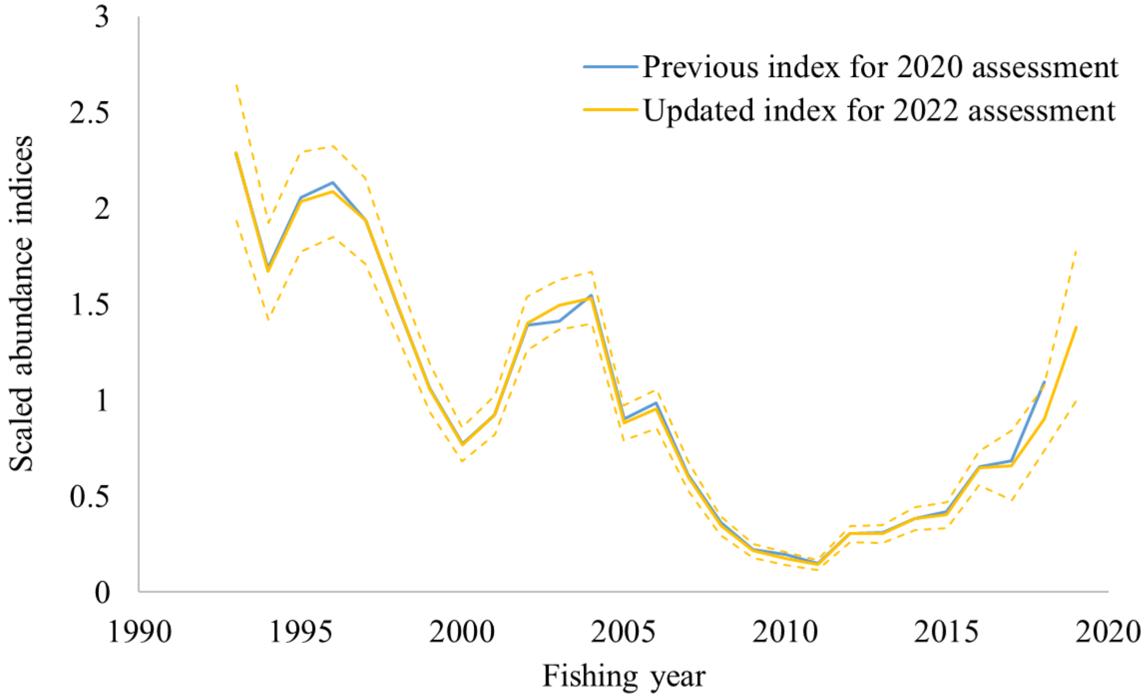

Figure 2 Comparison plot between updated abundance index with 95% confidential intervals and previous one for 2020 assessment without confidential interval.

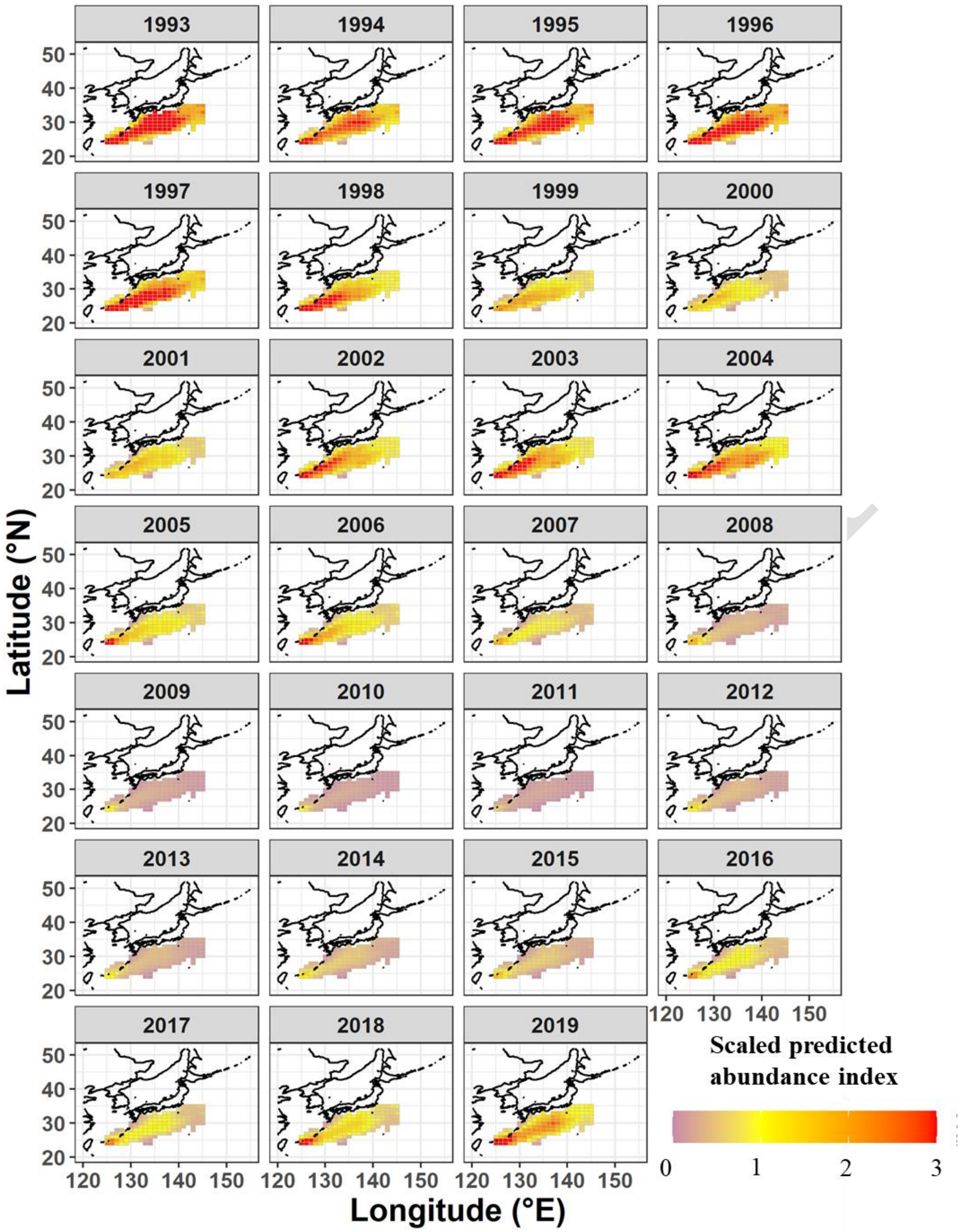

Figure 3. Annual distribution of scaled values of predicted abundance by fishing year.

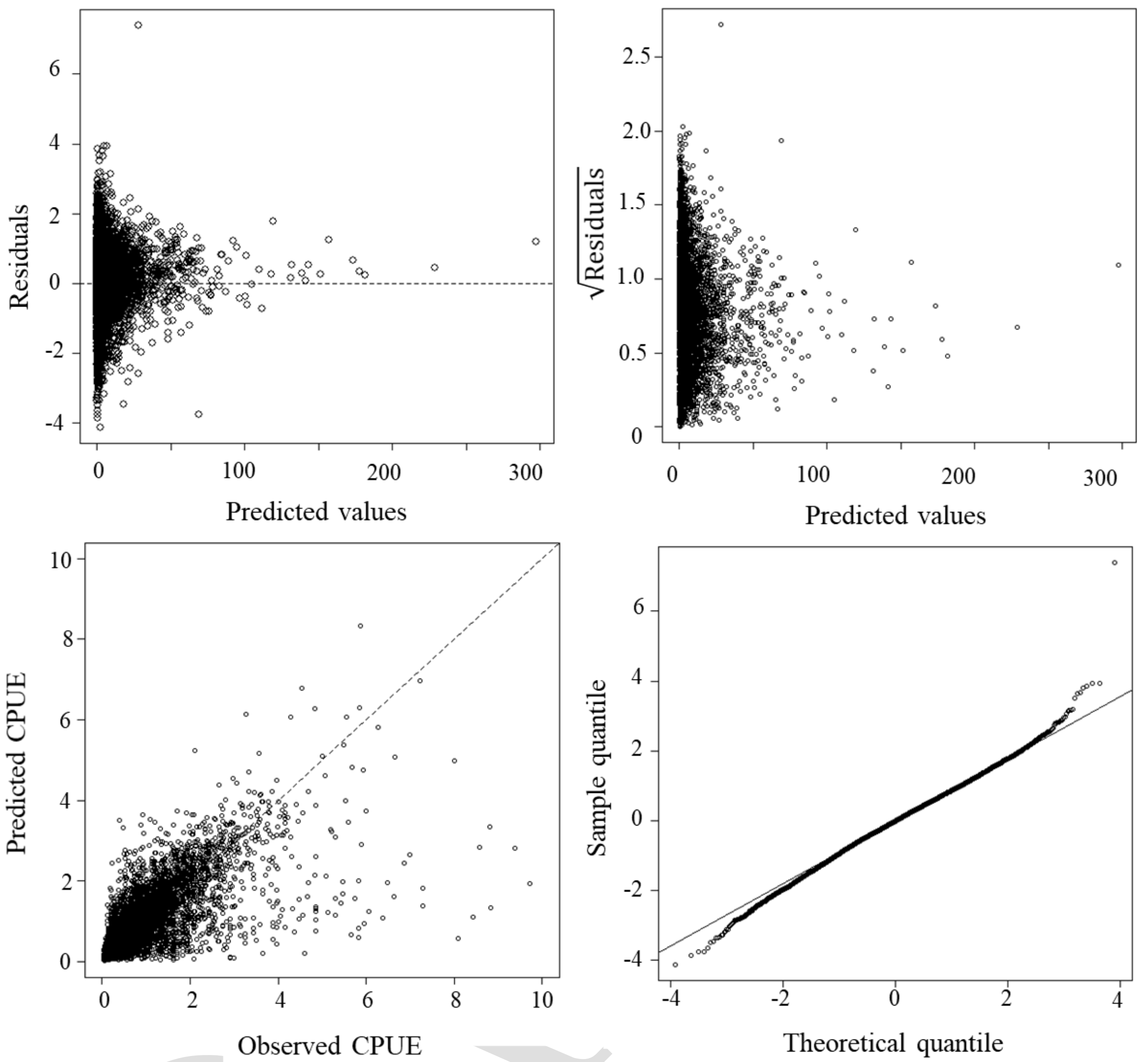

Figure 4. Diagnostic plots of goodness of fit for the spatiotemporal model for Pacific Bluefin Tuna for full model