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Update of Japanese annual catches for blue shark caught by Japanese offshore and distant-water longliner in the North Pacific Ocean from 1994 to 2018[1]

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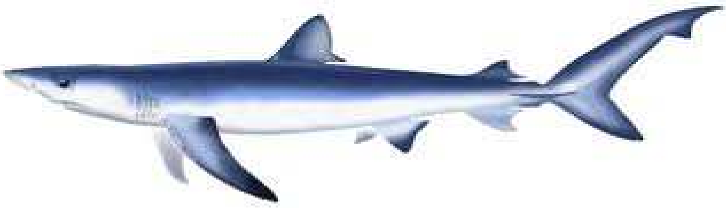

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Abstract

This working paper provides update of Japanese annual catches of blue shark (*Prionace glauca*) caught by Japanese offshore and distant-water longline fishery in the western and central North Pacific during 1994 and 2018. Since the landings of sharks is frequently underestimated due to the lower market value than any other teleost species such as tunas and billfishes, total annual catches including retained and discard/released catches were estimated using a product of standardized annual CPUEs and the fishing effort. The methods were almost the same as those used in the previous analyses. The results showed that the total estimated catches of North Pacific blue shark caught by Japanese offshore and distant-water longline fishery had been decreasing since 1995 until 2018 due to the reduction in the total fishing effort. The total estimated catches in recent five years were varied between 10,498 and 14,232 tons.

Introduction

Blue shark (*Prionace glauca*) in the North Pacific Ocean is occasionally targeted and frequently caught as bycatch by pelagic longline fisheries targeting tuna and billfish (Nakano and Seki, 2003). Since the market value of blue shark is lower than any other species such as tunas and billfishes, total catches (retained and discard/released catches) for blue shark landed in Japan is frequently underestimated. The total annual catches of blue shark caught by Japanese offshore and distant-water longline fishery in the North Pacific Ocean were therefore estimated using multiplying the annual CPUE by the fishing effort (Kai, 2016).

This document paper provides the updated total annual catch of North Pacific blue shark caught by Japanese offshore and distant-water longline fishery from 1994 to 2018.

Materials and Methods

Data source

Set-by-set logbook data from Japanese offshore and distant water longline fishery were used to standardize the CPUE and to estimate the total annual catches of North Pacific blue shark from 1994 to 2018. The details of the logbook data and the filtering methods for inappropriate data are described in Kai and Shiozaki (2016).

Definition of four fleets

In consideration of the changes in the target species, operational areas and effective fishing effort, Japanese offshore and distant-water longline fishery were separated into four fleets (Kai, 2016);

(i) Japanese offshore shallow-set longline fisheries (Kinkai-shallow),

(ii) Japanese offshore deep-set longline fisheries (Kinkai-deep),

(iii) Japanese distant-water shallow-set longline fisheries (Enyo-shallow),

(iv) Japanese distant-water deep-set longline fisheries (Enyo-deep),

where categories of "Kinkai" and "Enyo" were defined by gross tonnage of vessel (between 20 and 120 MT and larger than 120 MT), and categories of "shallow-set" and "deep-set" were separated by number of hooks between floats (HPF: smaller than 7 and larger than 6).

Estimation of total catch

The nominal CPUEs for four fleets were standardized using generalized linear models (GLMs) with the filtered data. Then the annual catches were estimated using the total number of hooks collected by whole Japanese offshore and distant-water fisheries as well as the CPUEs. The procedures are as follows:

(1) Annual CPUEs during 1994 and 2018 for four Japanese longline fleets were standardized using the following GLMs (Kai, 2016; Kai and Shiozaki, 2016):

For "Kinkai-shallow" and "Enyo-shallow",

$$E[Catch]=\exp\{Intercept + Y + A + Q + F + T + Y*T + Q*T\}offset(Effort)$$

$$Catch \sim \mathrm{NB}(\mu, k)$$

For "Kinkai-deep",

$$E[Catch]=\exp\{Intercept + Y + A + Q + G + A*G\}offset(Effort),$$

For "Enyo-deep",

$$E[Catch]=\exp\{Intercept + Y + A + Q + G + P\}offset(Effort),$$

where E[Catch] is expected total number of catch for North Pacific blue shark, Effort is the number of hooks (x 1000) as an offset variable, Y is year (1994-2018), A is area (1-4, **Fig. 1**), Q is quarter (Jan-Mar, Apr-Jun, Jul-Sept, Oct-Dec), F is fishery (Offshore and Distant-water), T is target (10^{th} percentile ranking of swordfish CPUE), G is two types of gear sets ("Shallower-deep" (HBF < 15) and "Deeper-deep" (HBF > 14)), and P is two areas of prefectures ("Hokkaido and Tohoku" and "Others"; see **Fig. 1**). These variables (Y, A, Q, F, T, G, and P) are defined as categorical explanatory variables. Y*T, Q*T, and A*G are interactions between Y and T, Q and T, and A and G respectively. NB stands for Negative Binomial model; μ is the mean; and k is the dispersion parameter. The diagnostics of the CPUE standardization for "Kinkai shallow" and "Kinkai deep" were summarized in **Appendix A**.

(2) Fleet specific total catch number was estimated through multiplying annual CPUEs by the total number of hooks.

(3) Total catch weight was calculated through multiplying the catch number by year, season and area by the average weight of blue shark by season and area (**Table 1**; Hiraoka *et al.*, 2013a,b; Kai *et al.*, 2014). The North Pacific blue shark is processed using two different processing methods: dress with fins ("Kesennuma dress") and dress without fins ("dress") for the offshore and distant water fisheries,

respectively. We therefore used different conversion factors:1.7 for “Kinkai” and 2.0 for “Enyo” (Semba *et al*., 2015). In summary, we corrected the weight data using two conversion factors:
(i)1.7/1.2 for Kinkai fleets
(ii) 2.0/1.2for Enyo fleet,
(4) Since Takahashi *et al*. (2012) suggested that the ratio of CPUE for “Enyo-deep” between research and commercial longline is 13:1, the annual total catch in weight including retained catch as well as discard/release of blue shark were raised by the value (i.e. 13 times).

Results

The estimated total catches (tons) of North Pacific blue shark caught by Japanese offshore and distant-water fishery tended to decrease since 1995 until 2018 due to the reduction in the fishing effort (number of hooks x 1000) (**Table2**, **Fig. 2**). The trends in the total annual catches were slightly different between updated and previous ones. Updated total annual catches by four different Japanese longline fleets showed that the total catch of offshore (“Kinkai”) shallow-set had increased since 1994 until 2001, and then it had decreased until 2011 and it maintained stable around 5,000 tons thereafter (**Table2**, **Fig. 3**). Estimated total catch of distant-water deep had sharply decreased in the early 1990s and it had reached to the lowest value in 2009 (2,932 tons). Thereafter, the estimated catches kept around 5,000 tons except in 2010 and 2011, and sharply decreased in 2019.

Discussion

Our results suggested that the total catches of North Pacific blue shark caught by Japanese offshore and distant-water longline fishery has been decreasing since 1994 until 2018 due to the reduction in the fishing effort (**Fig. 2**). It is therefore considered that the uptrends of the CPUE in recent eight years (2011-2019) for Japanese offshore and distant water sallow-set longline fishery (**Fig. 4**) is caused by the increase of abundance due to the reduction of the fishing pressure. The recent increase trends in abundance of blue shark was also supported by other CPUE trends predicted based on the spatiotemporal generalized-linear mixed model with the data of Japanese research and training vessels (Kai, 2019). The results also suggested that the abundance of blue shark in the central and western North Pacific has been increasing since 2009.

The abrupt increase of the catches in 2010 and 2011 for distant-water deep-set longline fishery (**Fig. 3**) was unexplainable due to insufficient information about the fishery. Tsunami in 2011 is unlikely to impact on the increase. We will need to explore the reasons in future work.

In this study, we used the same structures of GLM as those used in the previous analyses. Although, the method of the CPUE standardization for the Japanese offshore and distant-water shallow-set longline fishery was justified by Hiraoka *et al*. (2016), other methods for Japanese deep-set longline fishery are likely to include large uncertainties (see **Appendix B**). In the next full stock assessment, we should improve or validate the CPUE standardization methods using the state-of-the-art method such as spatiotemporal model (Thorson *et al*., 2015) with fishery independent data such as observer data or research and training vessel data.

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Table 1. Average body weight (kg) of blue shark by area and quarter.

Area	Quarter	Number	Weight (kg)	Average body weight (kg)
1	1	2112394	43494075	20.6
2	1	18223	468158	25.7
3	1	133384	3817282	28.6
4	1	78979	3233284	40.9
5	1	32714	898736	27.5
1	2	2809934	48387126	17.2
2	2	333508	5172216	15.5
3	2	402235	11597037	28.8
4	2	63589	2587959	40.7
5	2	42046	1180960	28.1
1	3	2717791	48350381	17.8
2	3	151114	2705509	17.9
3	3	65384	1921470	29.4
4	3	8945	346577	38.7
5	3	41259	1220596	29.6
1	4	1806861	35086170	19.4
2	4	50230	1156457	23.0
3	4	17799	507601	28.5
4	4	17860	690492	38.7
5	4	45893	1304058	28.4

Table 2. Annual estimated catch (tons), retained catch, and discard/released catches of North Pacific blue shark caught by Japanese offshore and distant-water longline fishery and the fishing effort (number of hooks x 1000) from 1994 to 2018.

Year	Offshore shallow			Offshore deep			Distant-water shallow			Distant-water deep			Total			
	Estimated catch	Retained catch	Discarded/ Released	Estimated catch	Retained catch	Discarded/ Released	Estimated catch	Retained catch	Discarded/ Released	Estimated catch	Retained catch	Discarded/ Released	Estimated catch	Retained catch	Discarded/ Released	Fishing effort
1994	9,800	8,247	1,553	2,911	1,778	1,133	919	514	405	18,277	1,244	17,034	31,908	11,783	20,124	141,110
1995	10,695	7,648	3,047	1,591	856	734	1,608	1,408	200	24,082	1,642	22,440	37,976	11,554	26,421	135,048
1996	9,463	8,211	1,252	2,577	1,475	1,102	1,560	1,159	401	14,064	1,043	13,022	27,665	11,888	15,777	115,851
1997	12,169	11,056	1,113	1,369	914	456	1,912	1,585	328	16,335	1,067	15,268	31,787	14,622	17,165	109,145
1998	11,986	10,854	1,132	960	405	555	2,469	1,683	786	15,542	1,128	14,414	30,958	14,070	16,887	110,074
1999	13,603	12,856	747	542	330	212	2,691	2,020	671	10,857	955	9,902	27,692	16,161	11,532	119,557
2000	18,196	16,038	2,158	489	75	413	2,463	2,305	159	6,717	670	6,047	27,865	19,088	8,777	111,511
2001	20,105	18,722	1,382	310	94	217	3,319	3,319	0	7,024	788	6,235	30,757	22,923	7,834	115,933
2002	17,556	16,746	811	273	89	184	2,415	2,305	109	4,921	491	4,430	25,165	19,630	5,534	105,098
2003	17,405	16,334	1,071	875	168	707	3,078	2,487	591	5,111	369	4,742	26,468	19,357	7,111	99,979
2004	14,849	14,025	823	1,785	153	1,632	4,795	4,297	498	4,591	325	4,266	26,019	18,800	7,220	89,950
2005	17,960	16,879	1,081	1,192	130	1,062	4,461	2,909	1,552	5,924	450	5,474	29,537	20,367	9,170	79,517
2006	14,708	13,987	721	2,229	187	2,042	4,882	3,063	1,819	4,364	341	4,023	26,182	17,578	8,604	75,538
2007	11,742	11,419	323	3,523	158	3,365	4,723	2,897	1,826	4,278	255	4,023	24,266	14,728	9,537	66,830
2008	10,095	10,095	0	763	99	665	4,282	2,775	1,506	4,013	280	3,733	19,153	13,248	5,904	61,582
2009	11,821	11,821	0	195	39	157	3,978	3,108	869	2,932	201	2,731	18,927	15,169	3,757	49,072
2010	9,989	9,989	0	97	19	78	3,760	3,153	607	8,464	364	8,100	22,311	13,525	8,785	49,493
2011	3,859	3,859	0	58	11	46	2,097	2,049	48	12,170	588	11,582	18,184	6,508	11,676	50,029
2012	5,592	5,498	94	37	37	0	3,251	2,994	257	3,604	185	3,419	12,485	8,714	3,770	46,210
2013	4,543	4,543	0	338	157	180	2,548	2,300	248	4,494	237	4,257	11,922	7,237	4,685	44,939
2014	5,218	5,218	0	265	155	110	2,020	2,020	0	4,597	374	4,223	12,101	7,768	4,333	46,082
2015	5,106	5,106	0	159	31	127	3,316	2,989	327	4,061	313	3,747	12,641	8,439	4,202	41,389
2016	4,842	4,544	298	166	33	134	4,421	4,149	272	4,453	380	4,074	13,882	9,105	4,777	33,206
2017	5,385	5,136	248	236	47	190	4,459	4,394	65	4,153	235	3,918	14,232	9,811	4,421	29,913
2018	4,349	4,319	29	438	86	352	4,169	3,783	385	1,543	134	1,409	10,498	8,323	2,175	28,628

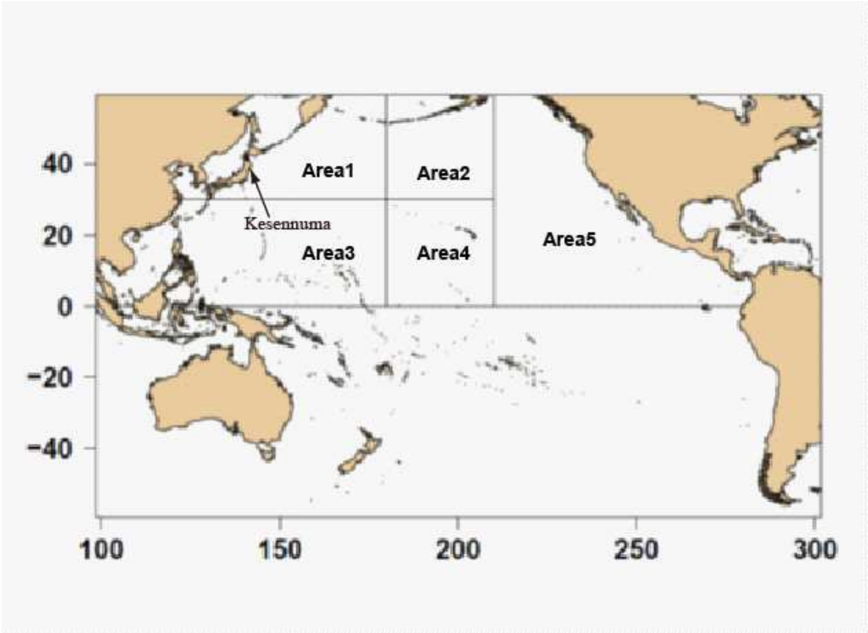

Figure 1. Area stratification used in the CPUE standardization for blue shark. “Kesennuma” is the major fishing port of the landings for blue sharks and swordfish.

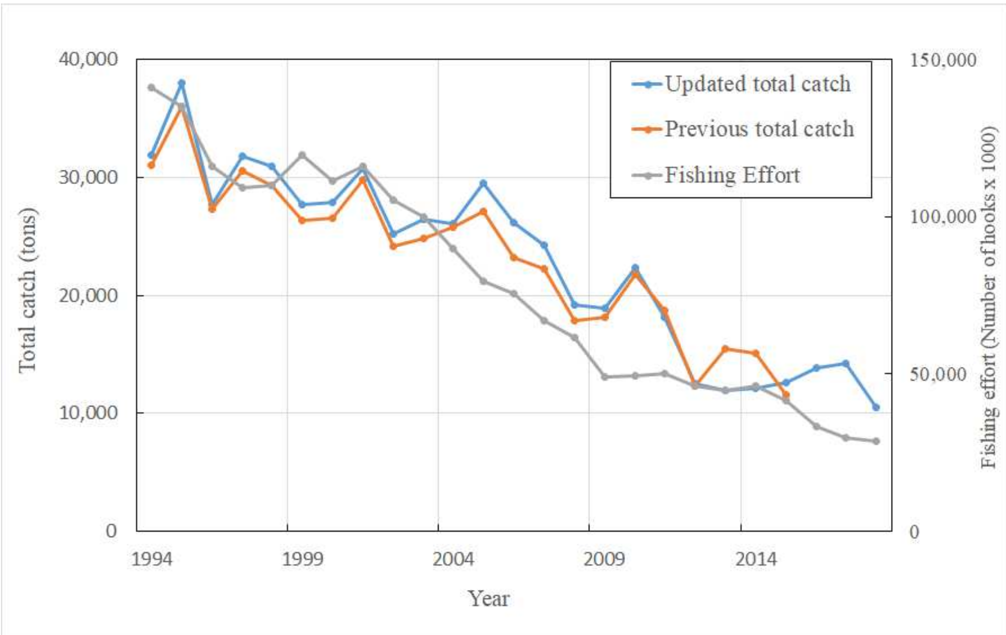

Figure 2. Annual updated total catches (tons), previous total catches (tons) and total fishing effort (number of hooks x 1000) from 1994 to 2018.

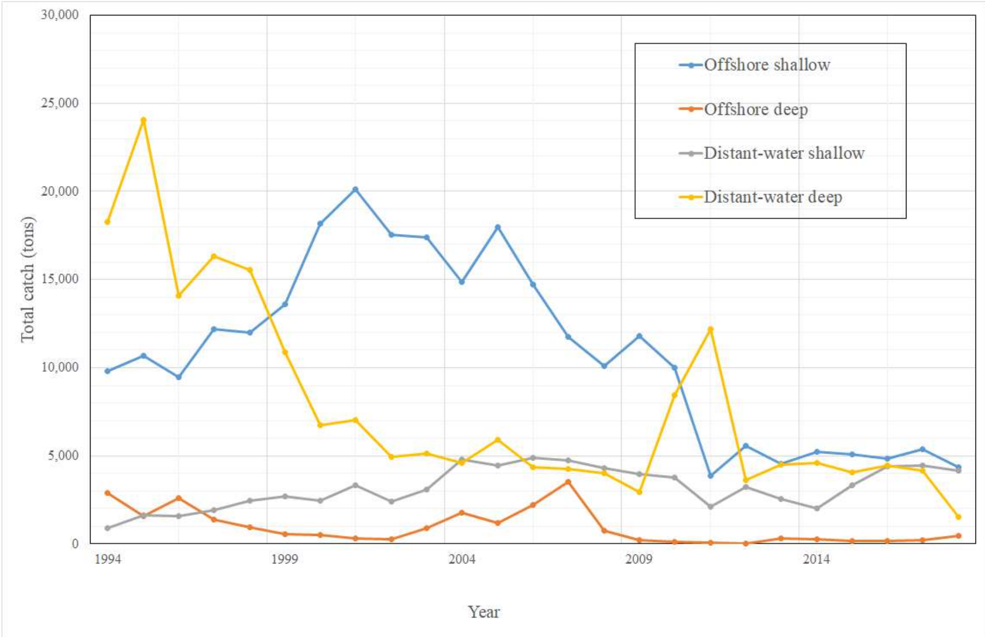

Figure 3. Annual total catches (tons) by Japanese longline fleets from 1994 to 2018.

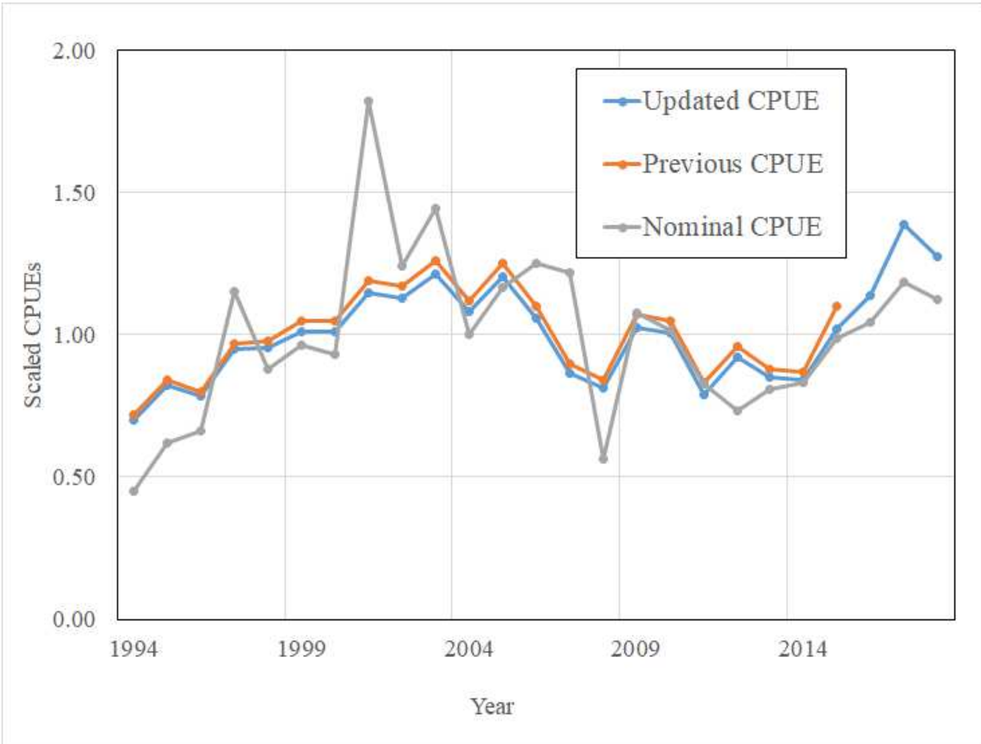

Figure 4. Annual changes in updated standardized CPUE, previous CPUE and nominal CPUE from 1994 to 2018.

Appendix A

The goodness of fit to the data of shallow-set longline fishery was examined using randomized quantile residuals (Dunn and Smyth, 1996) for the factors of all, year, season, area, fishery type and target effect in the GLM. The shape of the normal distribution of residuals and the residual patterns for all factors had no significant biases and entirely fitted well (**Fig. A1**). Q-Q plots indicated that the right ends of the plots were deviated from the straight line but the proportion of the outlier to all was small (**Fig. A1**).

The analysis of variance (ANOVA) was also conducted to check the effects of each factor on the fitting. The ANOVA table (**Table A1**) indicated that all factors were statistically significant ($p < 0.05$).

Table A1. Analysis of variance (ANOVA) summary table.

Response: blshark

	LR Chisq	Df	Pr(>Chisq)
as.factor(year)	2793.7	24	< 0.001
as.factor(qt)	3166	3	< 0.001
as.factor(area)	7704.3	3	< 0.001
as.factor(target)	2798.7	9	< 0.001
as.factor(gyogyoucode)	3.8	1	< 0.05
as.factor(year):as.factor(target)	5674.8	216	< 0.001
as.factor(qt):as.factor(target)	3484.7	27	< 0.001

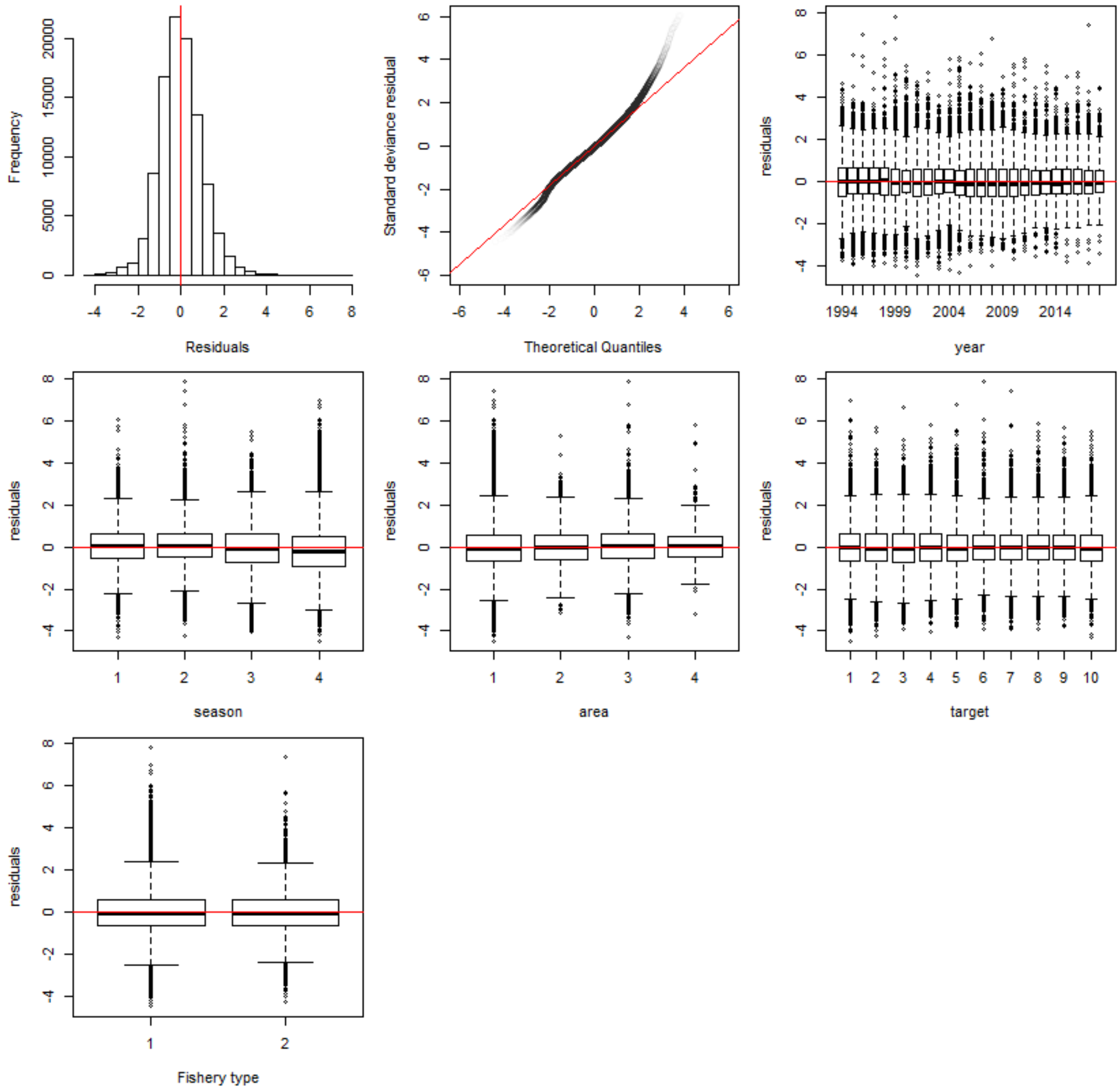

Figure A1. Diagnostic of the goodness of fit (randomized quantile residuals) to the data of Japanese offshore and distant water shallow-set longline fishery.

Appendix B

The standardized CPUEs for Japanese deep-set longline fisheries were shown in **Fig. B1** and the annual fishing effort (number of hooks; x one million) by four fleets were shown in **Table B1**.

Table B1. Annual fishing effort (number of hooks x one million) of Japanese offshore and distant-water longline fisheries operated in the North Pacific Ocean from 1994 to 2018.

Year	Offshore shallow	Offshore deep	Distant-water shallow	Distant-water deep
1994	24.0	2.0	51.7	63.4
1995	22.3	2.6	45.0	65.1
1996	19.6	2.9	41.8	51.6
1997	19.4	2.8	33.6	53.3
1998	19.0	3.7	30.7	56.6
1999	19.3	3.6	33.1	63.5
2000	22.2	3.2	30.4	55.8
2001	22.3	3.1	29.7	60.8
2002	20.5	2.8	24.2	57.5
2003	17.3	2.9	23.7	56.1
2004	16.2	5.1	19.6	49.1
2005	15.3	3.7	16.5	44.0
2006	14.1	4.6	17.1	39.7
2007	15.6	6.1	17.0	28.1
2008	13.9	5.9	16.2	25.6
2009	12.2	4.6	11.4	21.0
2010	11.3	4.8	11.2	22.2
2011	5.9	3.0	10.4	30.7
2012	6.9	3.7	11.0	24.6
2013	7.4	3.8	12.1	21.6
2014	7.9	2.8	10.8	24.6
2015	6.0	3.0	10.4	22.0
2016	5.1	3.8	10.7	13.5
2017	4.9	3.5	10.5	11.0
2018	4.6	3.2	9.1	11.8

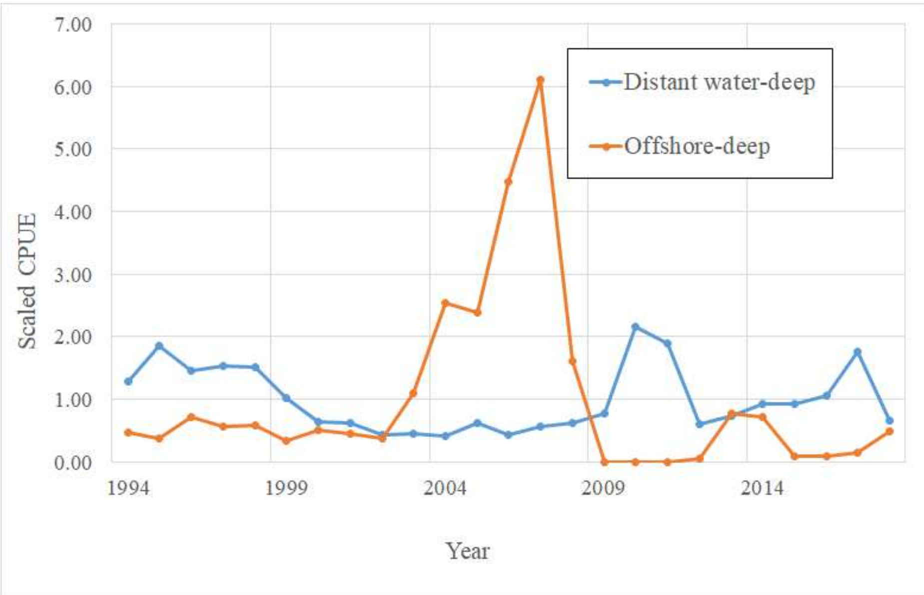

Figure B1. Annual changes in updated standardized CPUE for Japanese offshore and distant-water deep-set longline fisheries from 1994 to 2018.