ISC/21/SHARKWG-2/04

Update of Japanese annual catches for blue shark caught by Japanese offshore and distant water longliner in the North Pacific Ocean from 1994 to 2020[1]

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[1] Working document submitted to the ISC Shark Working Group Workshop, 9-19 November 2021, Web-meeting. **Document not to be cited without author's permission.**

Abstract

This working paper provides update of Japanese annual catches of blue shark (*Prionace glauca*) caught by Japanese offshore and distant-water longline fisheries in the North Pacific Ocean for 1994-2020. 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 total fishing efforts. The estimation methods of catches were substantially changed due to the changes in the CPUE standardization methods. Since the spatio-temporal models provide only the CPUEs scaled by the mean value, the scaled CPUEs was converted to absolute CPUEs using an average value of nominal CPUE. Then the catch number was estimated using the CPUEs and fishing effort. The calculations were separated by the shallow- and deep- sets longline fisheries. The annual catch number for shallow-set longline fishery was estimated using the season-year CPUEs of Japanese offshore and distant water shallow-set longline fishery with the fishing efforts of the shallow-set fishery, while those for deep-set longline fishery was estimated using the annual CPUEs of Japanese research and training vessels with the fishing efforts of the deep-set fishery. Further, the annual catch number for each fishery was converted to annual catch weight using an average weight of blue sharks caught by the fishery. The estimated annual catch weight showed a continuous decreasing trend in a gradual decline of the total fishing effort. The total catches in recent five years were varied between 6,674 and 9,240 MT.

Introduction

Blue shark (*Prionace glauca*) in the North Pacific Ocean is occasionally targeted and frequently caught as bycatch by Japanese offshore and distant-water 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) of blue shark caught by Japanese longline fisheries are frequently underreported. The annual catches of blue shark caught by Japanese offshore and distant-water longline fishery in the North Pacific Ocean were therefore estimated through multiplying the CPUE by the total fishing effort (Kai, 2016; Kai, 2019).

This document paper provides updates of annual catch for North Pacific blue shark caught by Japanese offshore and distant-water longline fishery from 1994 to 2020.

Materials and Methods

Data source

The author used (1) total fishing effort (i.e., number of hooks) of Japanese longline logbook data for 1994-2020, (2) standardized CPUE from 1994 to 2020, (3) an average of nominal CPUE from 1994 to 2020, and (4) season-area specific mean body weight of blue sharks (**Table A1**, Hiraoka et al., 2013).

Definition of four fleets

The author separated the Japanese offshore and distant-water longline fishery into four fleets in accordance with the previous analysis (Kai, 2016):

(1) Japanese offshore "Kinkai" shallow-set longline fisheries,

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

(3) Japanese offshore "Kinkai" deep-set longline fisheries,

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

where offshore fleet was defined by tonnage of vessels between 20 and 120 MT, distant water fleet was defined by vessels larger than 120 MT, "shallow-set" was defined by number of hooks between floats (HBF) smaller than 6, and "deep-set" was defined by HBF larger than 5.

Estimation of total catch for shallow-set longline fishery

(1) The season-year specific scaled CPUEs from the spatio-temporal model for Japanese Kinkai shallow longline fishery (Kai 2021a) were converted to the season-year specific absolute CPUEs using the mean value of nominal CPUEs from 1994 to 2020 (29.05 individual per 1000 hooks).

(2) Catch number by season, area and year was estimated through multiplying the season-year specific absolute CPUEs by the season-, area-, and year- specific total fishing effort (number of hooks).

(3) Catch weight by season, area and year was calculated through multiplying the catch number by the average weight of blue sharks by season and area.

(4) The catch number and weight were aggregated by the season and area, and then estimated the annual catch number and weight.

Estimation of total catch for deep-set longline fishery

(1) The year-specific scaled CPUEs from the spatio-temporal model for JRTV (Kai 2021b) were converted to the year-specific absolute CPUEs using the mean value of nominal CPUEs from 1994 to 2020 (3.976 individual per 1000 hooks).

(2) Catch number by season, area and year was estimated through multiplying the year-specific absolute CPUEs by season-, area-, and year-specific total fishing effort (number of hooks).

(3) Catch weight was calculated through multiplying the catch number by the average weight of blue sharks by season and area.

(4) The catch number and weight were aggregated by the season and area, and then estimated the annual catch number and weight.

Results

The estimated annual catch weight of blue sharks caught by Japanese offshore and distant-water longline fishery showed a continuous decreasing trend in a gradual decline of the total fishing effort (**Table 1**, **Fig. 1**). The estimated annual catch weight of blue sharks showed different trends by fleets (**Table 1**, **Fig. 2**). The annual catch weight of offshore shallow-set longline fishery had increased since 1994 until 2001, and then it had sharply decreased until 2011 and it maintained stable around 4,000 tons thereafter. Meanwhile, the total annual catch of offshore deep-set longline fishery had continuously decreased since 1994 and the catch in 2020 was the lowest level among four fleets. The annual catch weight of distant-water shallow-set longline fishery had slightly increased in 1990s and then the annual catch trend was stable ranging from 1,511 to 3,669 MT. The annual catch weight of distant-water deep-set longline fishery had sharply decreased from 1999 to 2008 and it maintained stable around 2,000 MT thereafter.

Discussion

Our results suggested that the annual catch weight of blue shark caught by Japanese offshore and distant-water longline fishery has been decreasing since 1994 until 2020 due to the continuous decrease of the annual fishing effort (**Table 1, Fig. 1**). The decreasing trends in the annual catch weight were similar between updated and previous ones, but the reduction rate of total catch between 1994 and 2015 was significantly different between them (0.37 and 0.28, respectively). The author considered that the different annual trends of the standardized CPUEs for two deep-sets fisheries (Kinkai and Enyo deep-sets) had large effects on the different outcomes because the annual trends in the standardized CPUEs were drastically changed between each of them and JRTVs (**Fig. A1**). The annual trends in the CPUEs for JRTVs was slightly changed throughout the period, while those for two deep-sets fisheries were occasionally fluctuated largely, though the annual changes in the fishing efforts for these fleets were stable with slightly decreasing trends (**Table A2**). One issue in the CPUE standardization for two deep-sets fisheries used in the previous analysis (Hiraoka et al., 2013; Kai and Shiozaki, 2016) was insufficient data filtering due to a lack of information about the total catches (i.e., retained and discard/released catches). In addition, the previous CPUE standardization for two deep-sets fisheries was conducted using GLMs without contemplating the methodology unlike for shallow-sets fisheries. Therefore, the author believes that the accuracy of updated catches for deep-set fisheries were much improved.

The annual CPUEs estimated from GLM was used for the catch estimation of shallow-set fishery in the past (Hiraoka et al., 2013; Kai and Shiozaki, 2016). In this study, the author improved the methodology of the CPUE standardization using the spatio-temporal GLMM in consideration with the year-season effect (Kai 2021b). One of the merits using the spatio-temporal model is the direct use of the year-season specific CPUEs which enabled us to estimate the catch number more accurately. The annual trends in the standardized CPUE for shallow-set fishery was compared between updated and previous ones (**Fig. A2**). The overall trends were almost similar but the magnitude of CPUEs were significantly different for some years. However, the author considered that the differences of the CPUEs had a small effect on the estimation of the catch compared to the catch estimation for deep-set fishery.

In future work, it will be capable of improving the accuracy of the catch estimation through improvement of the accuracy for the average body weight of blue shark by area and quarter (**Table A1**). The values of the table A1 seem reasonable considering the propensity of spatio-temporal segregation by season and area for blue sharks (Nakano and Stevens, 2008). However, the area-stratification used in the GLM for previous CPUE standardization (**Fig. A3**) was arbitrarily given. It is therefore meaningful to revisit the area-definition based on the latest information about the spatio-temporal movement of blue sharks in the North Pacific Ocean (e.g., Fujinami et al., 2021).

Finally, the use of annual catch number instead of annual catch weight might be reasonable as input value of stock synthesis (SS) model if there is a large uncertainty in the conversion from the catch number to catch weight in this paper.

Reference

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Table 1. Annual estimated catch (Metric tons; MT), retained catch, and discard/released catches of blue shark caught by Japanese offshore and distant-water longline fishery and the total fishing effort (number of hooks × one million) from 1994 to 2020.

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	14,334	5,798	8,537	7,667	1,302	6,365	715	261	455	11,396	1,424	9,972	34,112	8,784	25,328	136.2
1995	13,835	5,404	8,431	6,670	602	6,067	1,230	777	453	11,499	1,524	9,975	33,234	8,308	24,926	131.2
1996	11,212	5,791	5,421	6,117	1,064	5,053	1,356	676	679	8,664	1,161	7,503	27,349	8,692	18,656	111.4
1997	12,975	7,668	5,307	5,183	714	4,469	1,790	1,002	788	9,223	1,209	8,014	29,171	10,593	18,578	104.9
1998	12,933	7,643	5,290	4,470	305	4,166	2,293	1,007	1,286	9,351	1,042	8,309	29,047	9,997	19,050	105.4
1999	14,049	9,075	4,974	5,020	233	4,787	2,361	1,213	1,148	10,896	1,042	9,854	32,326	11,564	20,762	115.2
2000	14,281	11,321	2,960	4,010	50	3,960	2,113	1,383	730	8,753	763	7,990	29,156	13,516	15,640	107.9
2001	16,732	13,187	3,545	3,826	95	3,732	2,476	1,992	485	8,655	758	7,897	31,689	16,031	15,658	112.6
2002	14,945	11,821	3,125	2,711	62	2,649	2,063	1,384	679	7,768	640	7,128	27,486	13,906	13,580	101.2
2003	12,949	11,529	1,420	2,564	119	2,445	1,948	1,493	455	7,077	639	6,438	24,538	13,780	10,758	96.4
2004	11,558	9,900	1,658	1,945	108	1,837	3,669	2,578	1,091	5,902	534	5,368	23,075	13,121	9,954	84.9
2005	13,741	11,914	1,827	1,321	92	1,229	2,680	1,746	935	4,169	494	3,676	21,912	14,245	7,667	75.5
2006	11,571	9,889	1,683	1,275	132	1,143	2,763	1,927	836	3,551	377	3,174	19,160	12,324	6,835	70.3
2007	9,669	8,117	1,552	1,015	111	903	2,938	1,987	951	2,318	224	2,094	15,940	10,439	5,501	60.2
2008	8,285	7,126	1,160	655	70	586	2,714	1,949	765	1,315	191	1,124	12,970	9,336	3,634	55.6
2009	8,968	8,344	623	641	27	613	2,761	2,249	512	1,422	124	1,299	13,791	10,744	3,047	44.2
2010	8,463	7,048	1,416	762	17	745	3,350	2,353	997	2,117	227	1,890	14,693	9,645	5,048	43.3
2011	3,243	2,724	519	550	8	542	1,511	1,293	217	2,340	362	1,979	7,644	4,387	3,257	45.0
2012	4,526	3,881	645	443	20	423	2,175	1,797	378	1,729	112	1,618	8,873	5,810	3,063	39.1
2013	5,122	3,203	1,919	612	87	525	2,350	1,381	969	2,027	143	1,884	10,111	4,814	5,297	36.5
2014	5,667	3,683	1,984	739	71	668	1,802	1,219	583	3,015	226	2,789	11,223	5,199	6,023	39.2
2015	4,843	3,604	1,239	509	4	505	2,036	1,795	240	2,137	189	1,948	9,525	5,593	3,932	34.1
2016	3,720	3,207	513	645	4	641	2,760	2,489	271	1,781	230	1,551	8,906	5,931	2,976	24.7
2017	4,274	3,626	648	579	5	574	2,954	2,636	318	1,433	142	1,291	9,240	6,409	2,831	21.2
2018	4,077	3,221	857	531	36	495	2,676	2,520	155	1,405	82	1,323	8,689	5,859	2,829	22.0
2019	3,905	2,840	1,065	446	0	446	2,432	2,016	416	1,293	54	1,239	8,077	4,911	3,166	20.8
2020	3,199	1,980	1,219	341	0	341	2,041	1,363	679	1,093	14	1,079	6,674	3,357	3,317	18.6

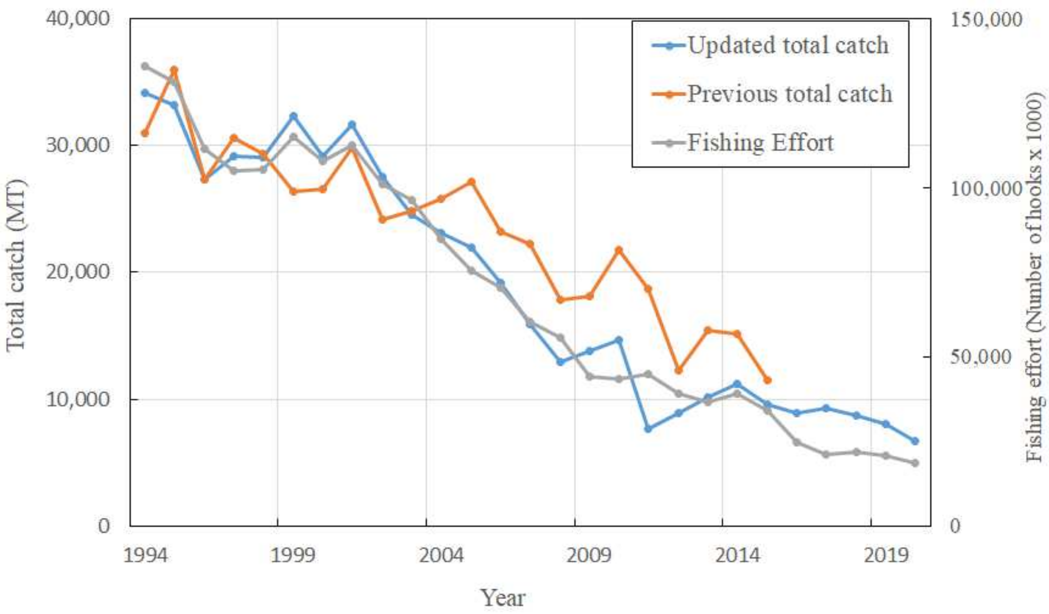

Figure 1. Annual changes in total catches (MT) of blue shark caught by Japanese offshore and distant-water longline fisheries and fishing effort (number of hooks × 1000) from 1994 to 2020.

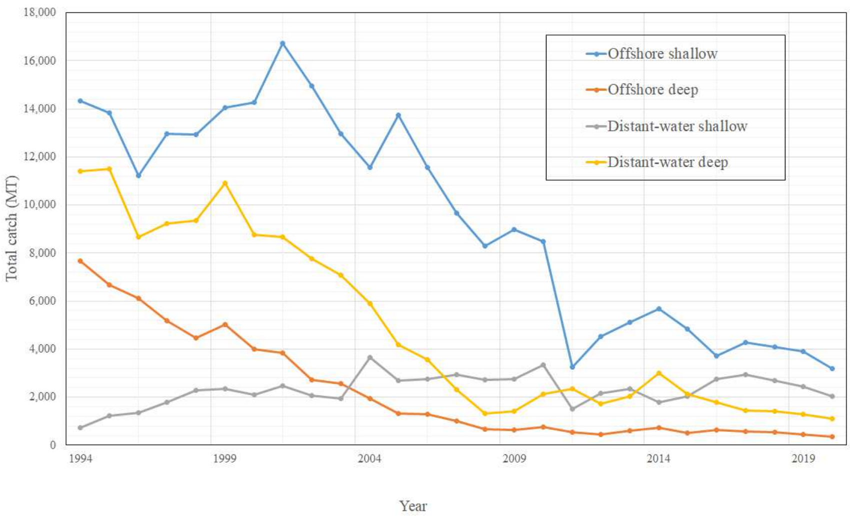

Figure 2. Fleet-specific annual catches (MT) of blue sharks caught by Japanese offshore and distant-water longline fisheries from 1994 to 2020.

Appendix tables and figures

Table A1. 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 A2. Annual fishing effort (number of hooks × one million) of Japanese offshore and distant-water longline fisheries operated in the North Pacific Ocean from 1994 to 2020. Note that the values of "Offshore deep" and "Distnat-water shallow" were swapped in the table of the previous paper, but the correct values were used in the estimation of the catches (Kai, 2019).

Year	Offshore shallow	Offshore deep	Distant-water shallow	Distant-water deep
1994	23.8	48.7	1.7	63.5
1995	22.2	43.4	2.0	65.4
1996	19.6	40.2	2.6	51.4
1997	18.9	32.6	2.7	53.2
1998	19.0	29.8	3.7	56.2
1999	19.3	32.8	3.6	62.7
2000	22.2	29.7	3.2	55.8
2001	22.3	29.2	3.1	60.7
2002	20.5	23.1	2.7	57.3
2003	17.3	22.8	2.9	56.0
2004	16.2	19.1	5.1	49.1
2005	15.3	15.8	3.7	44.0
2006	14.1	16.0	4.6	39.7
2007	15.7	15.8	6.0	28.1
2008	13.9	15.5	5.9	25.6
2009	12.2	10.6	4.6	21.0
2010	11.2	9.4	4.8	22.2
2011	5.9	8.0	3.0	30.7
2012	6.9	7.2	3.7	24.6
2013	7.4	7.1	3.8	21.6
2014	7.8	6.6	2.8	24.6
2015	6.0	5.9	3.0	22.0
2016	5.1	5.7	3.8	13.5
2017	4.9	4.9	3.5	11.0
2018	5.0	4.7	3.5	11.9
2019	4.9	4.2	3.2	11.4
2020	5.0	3.6	3.2	9.7

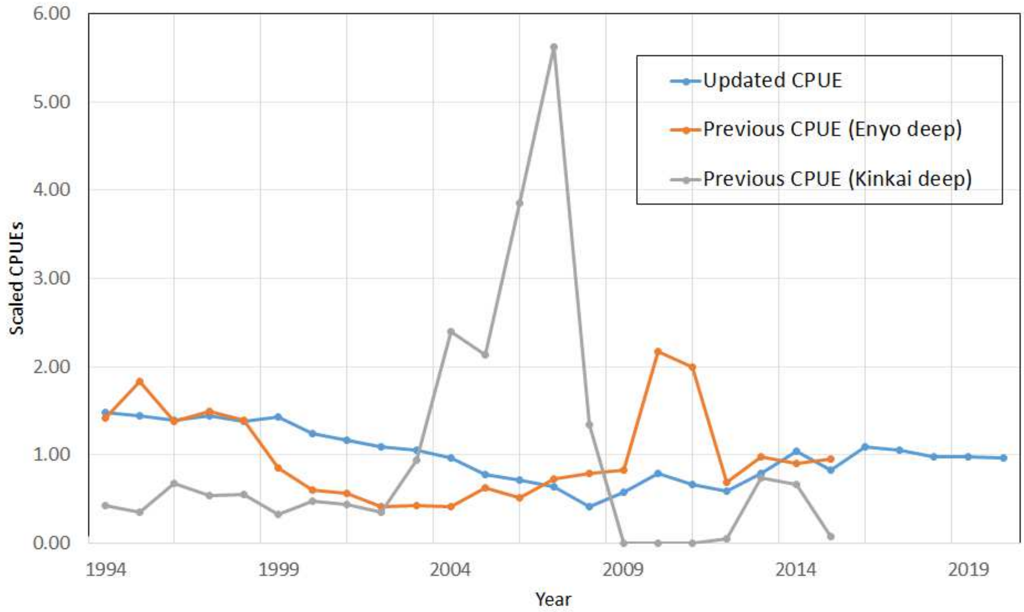

Figure A1. Annual changes in standardized CPUEs for Japanese deep-set longline fisheries from 1994 to 2020.

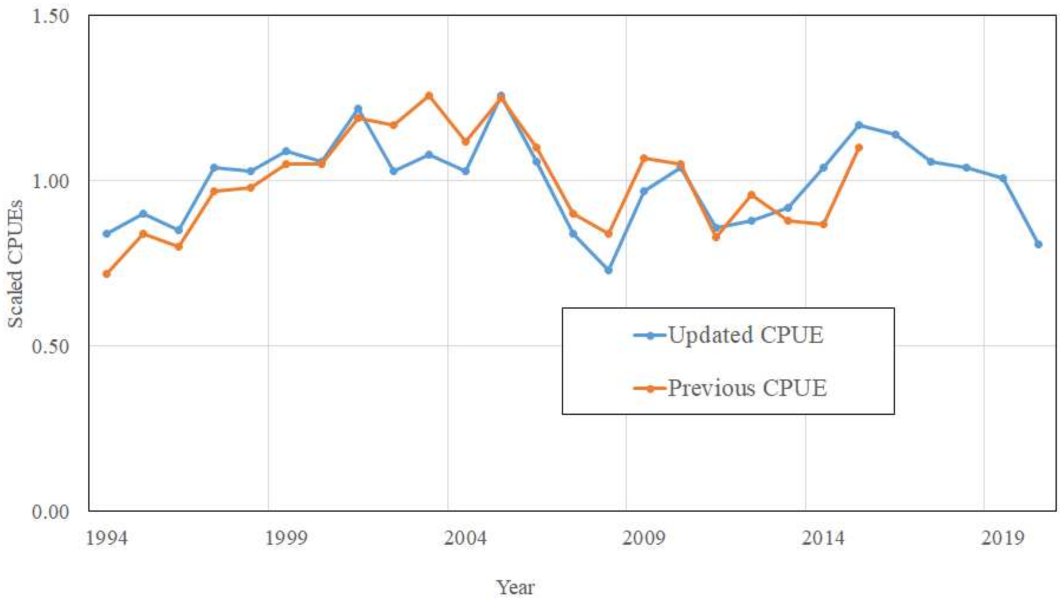

Figure A2. Annual changes in standardized CPUE for Japanese shallow-set longline fisheries from 1994 to 2020.

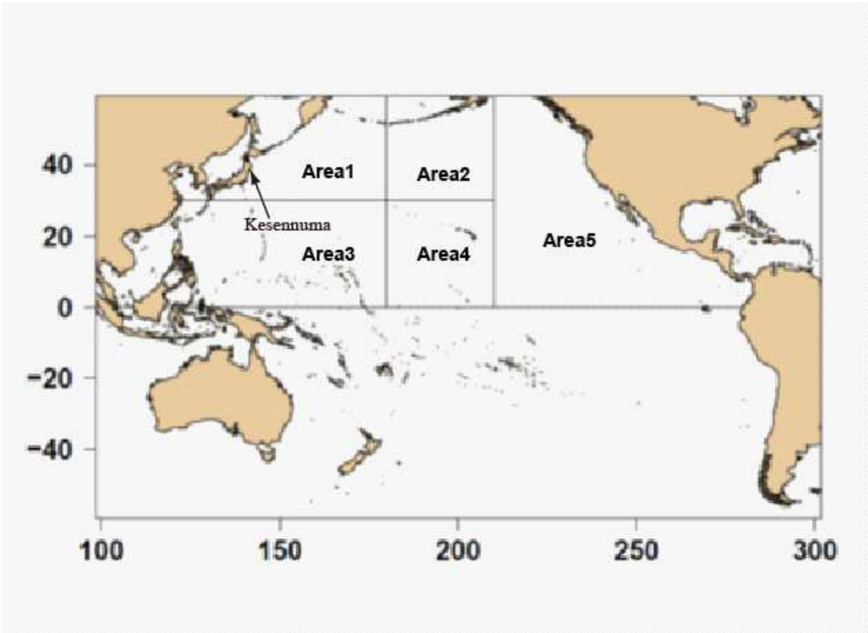

Figure A3. Area stratification for the average body weight of blue shark. The area stratification was used in the previous CPUE standardization for Japanese shallow-set longline fishery (Hiraoka et al., 2013; Kai and Shiozaki, 2016). "Kesennuma" is the major fishing port of the landings for blue sharks and swordfish.