Representativeness of two Japanese longline CPUEs as abundance index of North Pacific shortfin mako[1]

Mikihiko Kai[2]
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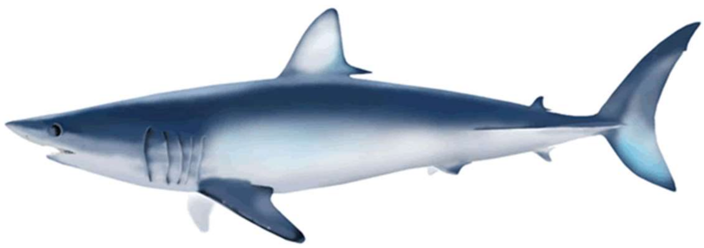
[2]Fisheries Resources Institute, Highly Migratory Resources Division,
Japan Fishery Research and Education Agency
2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, JAPAN
Email: kai_mikihiko61@fra.go.jp



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Abstract

Japan provided two standardized CPUEs for the stock assessment of shortfin mako in 2024. One is the CPUE of shortfin mako caught by Japanese offshore and distant water commercial longline fishery ("Kinkai Shallow") and the other is those caught by Japanese research and training vessel (JRTVs). The fishery -dependent and -independent data showed inconsistent annual trends. Those two CPUEs were compared from the multiple perspective to discuss the representativeness of the CPUEs as an abundance index of the North Pacific shortfin mako. Both CPUEs may be representative of the abundance indices because of the wide area coverages, wide coverage of the size classes, and statistical soundness of the spatiotemporal model. However, the "JRTV" CPUE has weak points such as lower catch and effort data coverage and higher variability of the predicted CPUEs compared to the "Kinkai Shallow" CPUE. In addition, "Kinkai Shallow" CPUE indicated the plausible annual increasing trends compared to those in the previous analysis in 2017. **The author therefore recommends using the "Kinkai Shallow" CPUE as the abundance index of the North Pacific shortfin mako.** Further discussion is necessary to determine the representative abundance indices of shortfin mako during the upcoming data prep. meeting from the other factors such as a consistency of annual trends with the other CPUEs.

Introduction

Abundance index is one of the most important factors to govern the accuracy of the stock assessment. Stock assessment of shortfin mako, *Isurus oxyrincus*, in the North Pacific Ocean is scheduled in 2024. For the stock assessment, Japan provided two standardized catch per unit effort (CPUEs) of shortfin mako caught by large-scale vessels larger than 20 metric tons (MT) for 1994-2022 (Kai, 2023a, b). One is the CPUE of shortfin mako caught by Japanese offshore and distant water commercial longline fishery ("Kinkai-Shallow") operated mainly in the western North Pacific Ocean (**Fig. 1**). This fishery mainly targets swordfish, *Xiphias gladius*, and blue shark, *Prionace glauca*, and change their target from swordfish to blue shark and vice versa by season (Kai, 2023a). The gear configuration is chiefly consisted of shallow set (number of hooks between floats; HBF: 3~5). The other is the CPUE of shortfin mako caught by Japanese research and training vessel (JRTVs) operated in the western and central North Pacific Ocean (**Fig. 1**) but mainly in the water around Hawaii (Kai, 2023b). This survey is fishery independent and mainly targets tropical tuna such as a bigeye-tuna, *Thunnus obesus*, and there is no targeting shift. The gear configuration is mostly consisted of deep set (HBF: 6–16).

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The nominal CPUEs for the two fleets were standardized using the spatio-temporal generalized linear mixed model (GLMM) developed by Thorson (2019) after the set-by-set logbook data was filtered to remove under/mis-reporting data (Kai, 2023a, b). The year-season specific spatiotemporal model (Thorson et al., 2020) was used for the shallow-set fishery to remove the effect of targeting shifts. Meanwhile, the year-specific spatiotemporal model (Kai, 2019) was used for the deep-set survey as there is no issue about the targeting shift by area and season.

The main objective of this working paper is to compare the outcomes of standardized CPUEs for two main Japanese fleets (i.e., "Kinkai shallow" and "JRTV") and to discuss the representativeness of the CPUEs as abundance index of the North Pacific shortfin mako.

Annual trends in two CPUEs

The annual standardized CPUEs indicated inconsistent trend (**Table 1**, **Fig. 2**). The CPUE of "Kinkai shallow" showed a continuous increase trend since 1994 until 2015 with narrower 95% confidence intervals, and then slightly decreased until 2022 with wider confidence intervals. Meanwhile, those of "JRTV" showed an almost flat trend from 1994 to 2005 with wider confidence intervals, and then those showed a decreasing trend with large fluctuations until 2022.

Evaluation of variance for two annual CPUEs

The variances of the predicted annual CPUEs were evaluated by fitting the loess smoother to the point estimates (**Fig. 3**). The estimated curve of "Kinkai shallow" showed a continuous increasing trend until around 2015 and slightly decreased onward. By contrast, those of "JRTV" showed flat or a slightly increasing trend until around 2005, and then decreased until 2013 and again slightly increased until 2022. The annual residual plots showed random fluctuations for both fleets, however, the outliers were observed in 2007, 2013, 2015 and 2016 for "JRTV". In addition, the standard deviation of "Kinkai shallow" (0.093) was much smaller than those of "JRTV" (0.232). These results suggested that the predicted CPUE of the "Kinkai shallow" is better than that of the "JRTV" considering the small variance.

Spatial coverage of overall data after filtering

Overall spatial distribution of fishing effort (total number of hooks on the logscale) for two Japanese CPUEs ("Kinkai shallow" and "JRTV") were shown in **Fig. 1**. The spatial coverage of “JRTV” is much broader than that of “Kinkai shallow”. However, the main operational area of “JRTV” is limited to the waters in the central North Pacific Ocean around Hawaii islands. Meanwhile, the main operational area of “Kinkai shallow” is spread evenly in the western North Pacific Ocean. These results suggested that the CPUE of “Kinkai shallow” indicates the abundance indices of shortfin mako in the western North Pacific Ocean, while the CPUE of “JRTV” indicates the abundance indices of shortfin mako in the central North Pacific Ocean.

Spatial coverage of year-specific data after filtering

Year-specific spatial distribution of fishing effort (total number of hooks on the logscale) for two Japanese CPUEs (“Kinkai shallow” and “JRTV”) was shown in **Figs. 4** and **5**, respectively. Both spatial maps clearly showed the shrinkage of the operational area in recent years due to the continuous decline of fishing effort (**Fig. 6**). The phenomenon was notable after 2006 and 2011 for “Kinkai shallow” and “JRTV”, respectively. These decreasing trends in the catch and effort have a large impact on the standardization of CPUE, however, the spatial temporal GLMM model used in the CPUE standardization have a characteristic to impute the lacking spatiotemporal data using the correlation among them. It is therefore considered that the effect of the spatial shrinkage recent years is small when we use the recent predicted CPUEs as abundance indices of shortfin mako in the North Pacific Ocean.

The key points were summarized in **Table 2** to evaluate the representativeness of the CPUEs as abundance index of North Pacific shortfin mako.

Discussions

The inconsistent trends between fishery-dependent and -independent data for shortfin mako were probably caused by multiple factors: 1) the main operational areas are different by season between commercial fishery and JRTV and may cause spatial and temporal different catchability due to different fish density by area and time, 2) the gear-configurations such as a depth of gear-setting are different between two fleets and may cause different catchability due to different fish density by depth, 3) the selectivity and availability of male and female shortfin mako are different between two fleets and may cause different catchability by size classes and sexes. The key point to solve these issues of the divergent indices for shortfin mako is to develop the method for synthesizing the fishery dependent data with fishery-independent data because the predicted catch rates for two Japanese fleets might be only representing the sub-population in the water of western North Pacific Ocean where a great number of immature and sub-adult shortfin mako were caught by commercial longline fisheries and water in the central North Pacific Ocean around Hawaii where larger shortfin mako were caught by JRTV, respectively. The combined data with a single model structure therefore could enhance the precision of the estimated catch rate for shortfin mako, especially for the catch rates in the water of western and central North Pacific Ocean. However, calibration of the catchability is required due to the different size specific selectivity and availability by area, time, and vessels, when scientist treats simultaneously fishery-dependent and -independent data.

Longline fishery in the western and eastern North Pacific Ocean tends to catch a shortfin mako smaller than 150 cm precaudal length (PCL), whereas longline fishery in the central North Pacific Ocean tends to catch female and male larger than 150 cm PCL using the deep-set fishery, and they were on average larger south of 30 °N (Sippel et al., 2014).
Since the average maturity size of female of shortfin mako in the North Pacific is 233 cm PCL (Semba et al., 2021), two abundance indices are inappropriate to represent the abundance trends of adult spawning female fish. However, "Kinkai shallow" fleet operates in the coastal and offshore area off Japan where pupping ground of shortfin mako and "JRTV" fleet operates in the water around Hawaii where female larger than 200 cm is occasionally caught (Semba et al., 2021). These facts supports that both "Kinkai shallow" and JRTV CPUEs can be candidate as abundance indices of the North Pacific shortfin mako.

Kai et al. (2017) developed a length-disaggregated spatio-temporal delta-GLMM and applied the method to fishery-dependent catch rates of shortfin mako in the western and central North Pacific Ocean. The size specific catch rates provided an indication that there was an increasing trend in stock abundance (i.e., immature, and subadult and adult) since 2008 until 2014. In addition, Kai (2023) developed a length-aggregated spatio-temporal delta-GLMM in consideration with the seasonal and interannual variations of the density in the model. The estimated annual changes in the CPUE of shortfin mako revealed an upward trend from 1994 to 2014. These results suggested that the abundance indices of shortfin mako caught by shallow-set fishery in the western North Pacific Ocean have a similar annual trend regardless of the catch size classes of shortfin mako except for the size class of juvenile (**Fig. 7**).

Based on the discussions above, **the author recommends using the predicted annual CPUEs of shortfin mako caught by "Kinkai shallow" as abundance indices of the**

North Pacific shortfin mako because of a wide coverage of the main distributional areas of shortfin mako where the temperate water (20-45 °N and 130 °E-160°W), wide coverage of the size classes (approximately 60~250 cm PCL) as well as both sexes for shortfin mako, statistical soundness of the spatiotemporal model, higher catch and effort data coverage in the North Pacific Ocean, lower variability of predicted CPUE compared to those for JRTV data and possible annual increasing trends compared to those in the previous analysis in 2017 (Kai et al., 2017). On the other hand, the CPUE of JRTVs may be representative abundance index of the North Pacific shortfin mako because of the wide area coverages of JRTV operations in the entire North Pacific (**Fig. 1 and 6**), wide coverage of the size classes (approximately 60~300 cm PCL) as well as both sexes especially for adult females of shortfin mako, and statistical soundness of the spatiotemporal model. However, lower catch and effort data coverage and higher variability of predicted CPUEs are weak point to recommend this abundance index. Further discussion is necessary to determine the abundance index of shortfin mako during the upcoming data prep. meeting from the multiple perspective such as a consistency of the annual trends with the other CPUEs, the comparisons of the following factors with the other CPUEs: the spatial extent of the data used in the standardization, the percentage of fishing effort covered, the data resolution, and the modelling diagnostics, etc..

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Tables

Table 1. Annual nominal CPUE, annual standardized CPUE, annual CV of the standardized CPUE, and annual fishing effort (number of hooks).

Year	Nominal-CPUE Shallow	Nominal-CPUE Deep	Standardized CPUE-Shallow	Standardized CPUE-Deep	CV-Shallow	CV-Deep	Hooks-Shallow	Hooks-Deep
1994	0.16	0.93	0.41	1.09	0.25	0.20	20.5	4.83
1995	0.22	0.89	0.51	0.99	0.23	0.19	18.1	4.63
1996	0.31	0.79	0.65	1.03	0.20	0.21	19.3	4.52
1997	0.43	1.03	0.63	1.03	0.19	0.18	18.0	4.25
1998	0.45	1.24	0.65	1.09	0.17	0.22	18.2	2.76
1999	0.53	1.17	0.66	1.33	0.17	0.50	20.1	0.86
2000	0.62	1.20	0.65	1.37	0.16	0.27	23.3	2.73
2001	0.54	0.9	0.73	1.01	0.15	0.20	22.9	2.69
2002	0.52	1.09	0.66	1.10	0.16	0.20	20.4	2.89
2003	0.63	1.12	0.75	1.17	0.13	0.21	18.0	2.66
2004	0.67	1.10	0.81	1.10	0.14	0.20	18.3	2.89
2005	0.89	1.03	0.96	1.09	0.12	0.21	16.6	2.08
2006	0.90	1.24	1.00	1.37	0.13	0.26	16.1	2.08
2007	0.96	1.08	1.06	1.74	0.12	0.38	18.2	1.45
2008	0.85	1.08	0.91	1.07	0.14	0.24	15.8	1.30
2009	1.13	0.64	1.21	0.86	0.12	0.25	14.4	0.67
2010	1.03	0.77	1.14	0.93	0.13	0.30	13.8	0.66
2011	1.34	0.69	1.30	0.67	0.15	0.19	7.5	0.80
2012	1.36	0.97	1.40	0.71	0.15	0.17	9.2	0.76
2013	0.95	0.52	1.16	0.34	0.16	0.11	9.5	1.07
2014	1.39	0.93	1.56	0.76	0.15	0.19	9.8	1.47
2015	1.65	1.68	1.52	1.32	0.15	0.36	8.1	1.24
2016	2.16	1.58	1.42	1.09	0.16	0.23	7.8	1.19
2017	1.73	0.83	1.40	0.75	0.17	0.17	7.3	1.19
2018	1.82	1.05	1.39	0.85	0.19	0.22	7.6	1.13
2019	1.71	1.10	1.24	0.78	0.18	0.24	7.2	0.91
2020	1.05	0.70	0.98	0.67	0.18	0.23	7.6	0.52
2021	1.07	0.90	1.10	0.92	0.18	0.33	5.7	0.35
2022	1.95	0.74	1.15	0.79	0.18	0.28	3.9	0.57

Table 2. CPUE evaluation table for two Japanese fleets.

	Kinkai shallow	JRTV
Data source	Logbook (commercial fishery)	Logbook (survey by research and training vessel)
Time of period	1994-2022	1994-2022
Main operational area	Western-NPO	Central NPO
Gear setting	Shallow-set (HBF:3-5)	Deep-set (HBF: 6-16)
Spatial coverage in NPO	Middle	High
Data coverage (catch and effort) in NPO	High	Low
Data filtering	Suficient	Sufficient
Type of model	spatio-temporal GLMM	spatio-temporal GLMM
Consideration of key factors	Sufficient	Sufficient
Model diagnostics	Well	Well
Variability (CV or SD)	Low	High
Continuous trends	Yes	No
Biologically implausible increase trends	No	Yes (2005-2007, 2013-2015)
Range of body size	60 - 250cm PCL	60 - 300 cm PCL

Figures

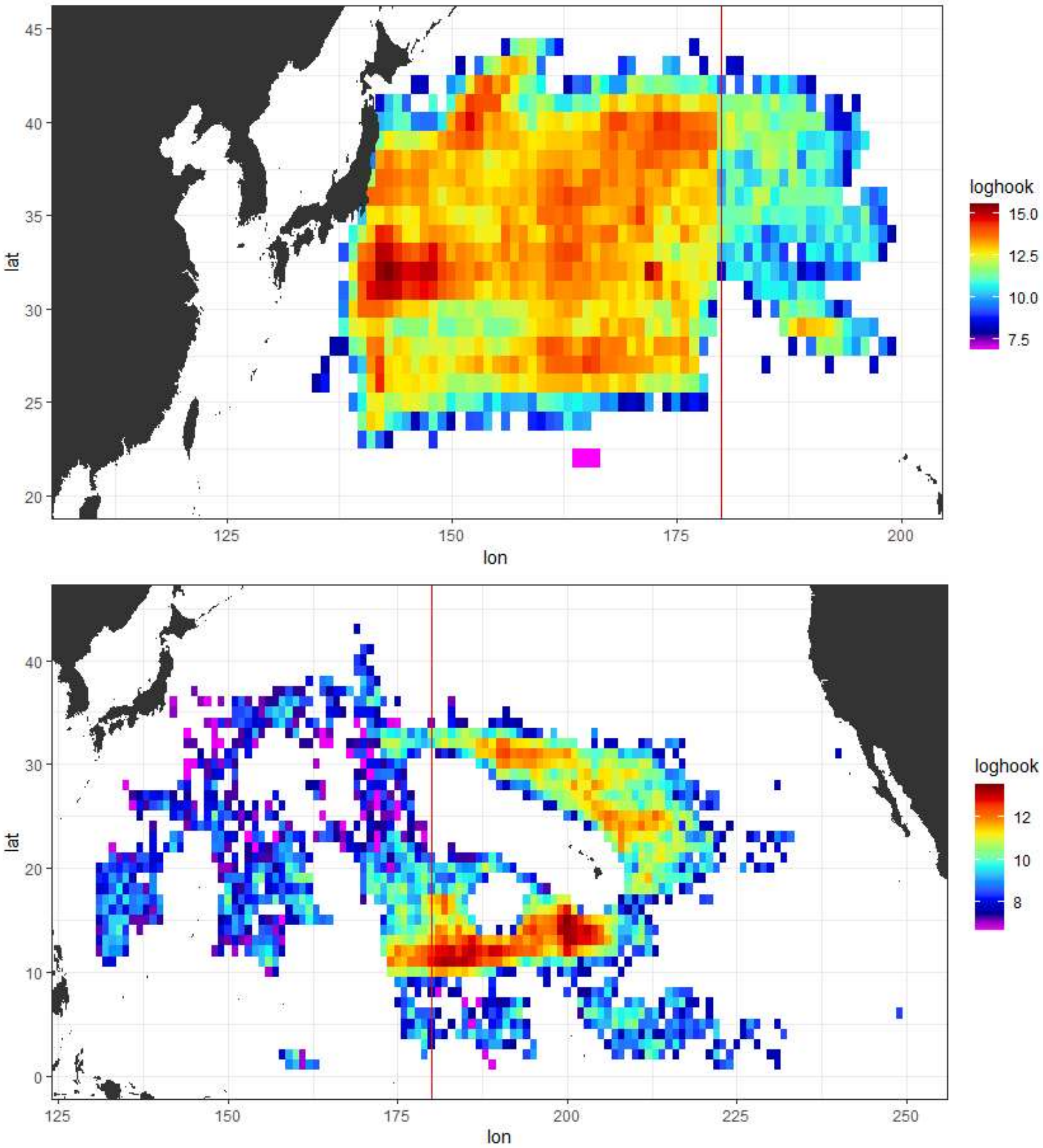

Figure 1. Spatial coverage of data (total number of hooks on the logscale) used in the CPUE standardization for two Japanese CPUEs: Japanese "Kinkai shallow" longline fishery (upper panel) and JRTV survey (lower panel). The data were filtered to remove under/mis-reporting data. The red vertical line denotes the international date line.

Figure 2. Annual predicted CPUE relative to its average for Japanese "Kinkai shallow" longline fishery (blue) and JRTV (red). Shadow denotes 95% confidence intervals and horizontal dotted line denotes mean of relative values (1.0).

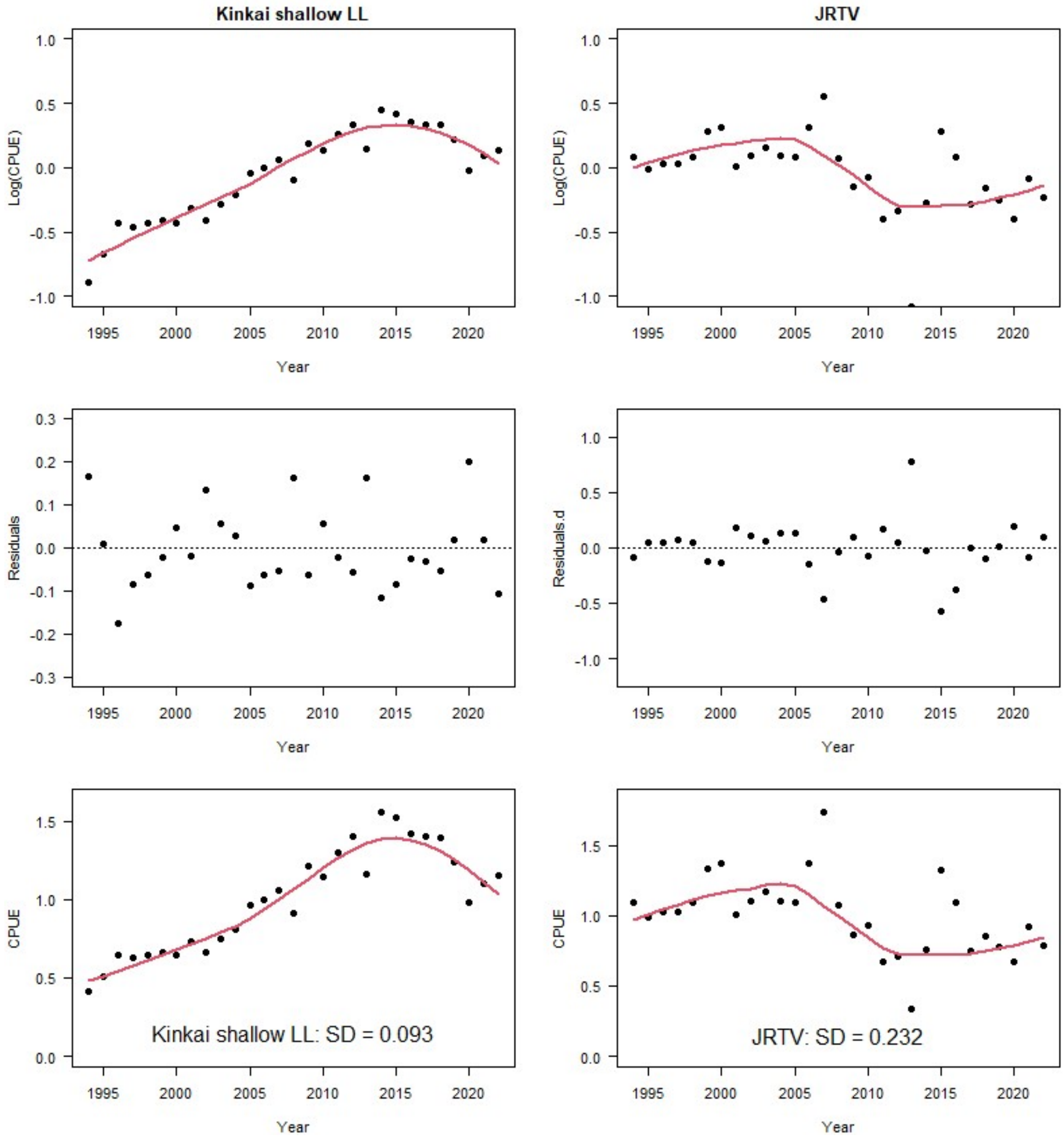

Figure 3. Evaluation of variance of predicted CPUEs for two Japanese CPUEs: Japanese "Kinkai shallow" longline fishery (left panel) and JRTV survey (right panel). Fitting the loess smoother (red curve) to the annual predicted CPUEs on the log scale (top panel), annual residual plot between predicted CPUE and loess smoother on the log-scale (middle panel) and fitting the loess smoother to the annual predicted CPUEs (bottom panel).

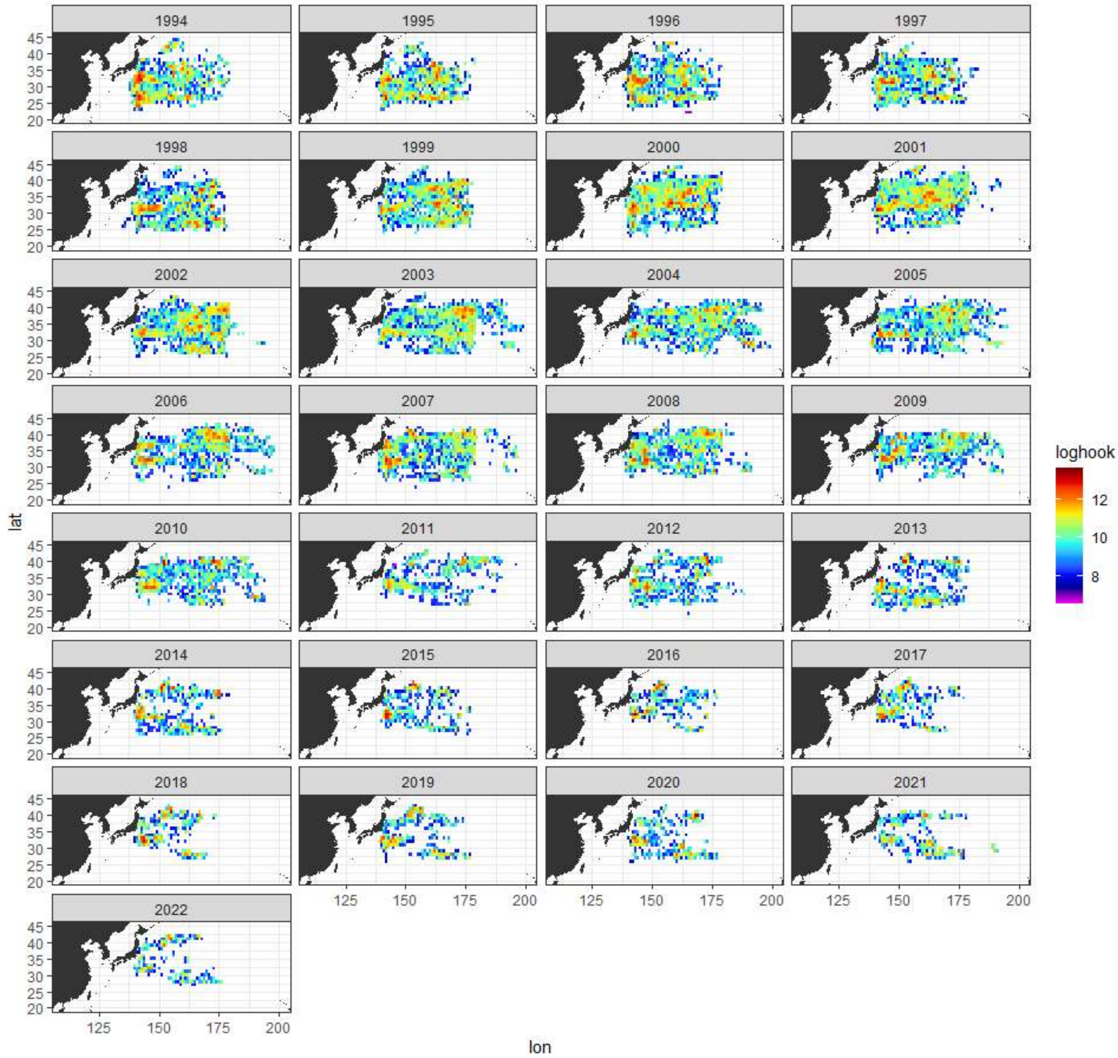

Figure 4. Year specific spatial distribution of fishing effort (total number of hooks on the logscale) used in the CPUE standardization for Japanese "Kinkai shallow" longline fishery from 1994 to 2022.

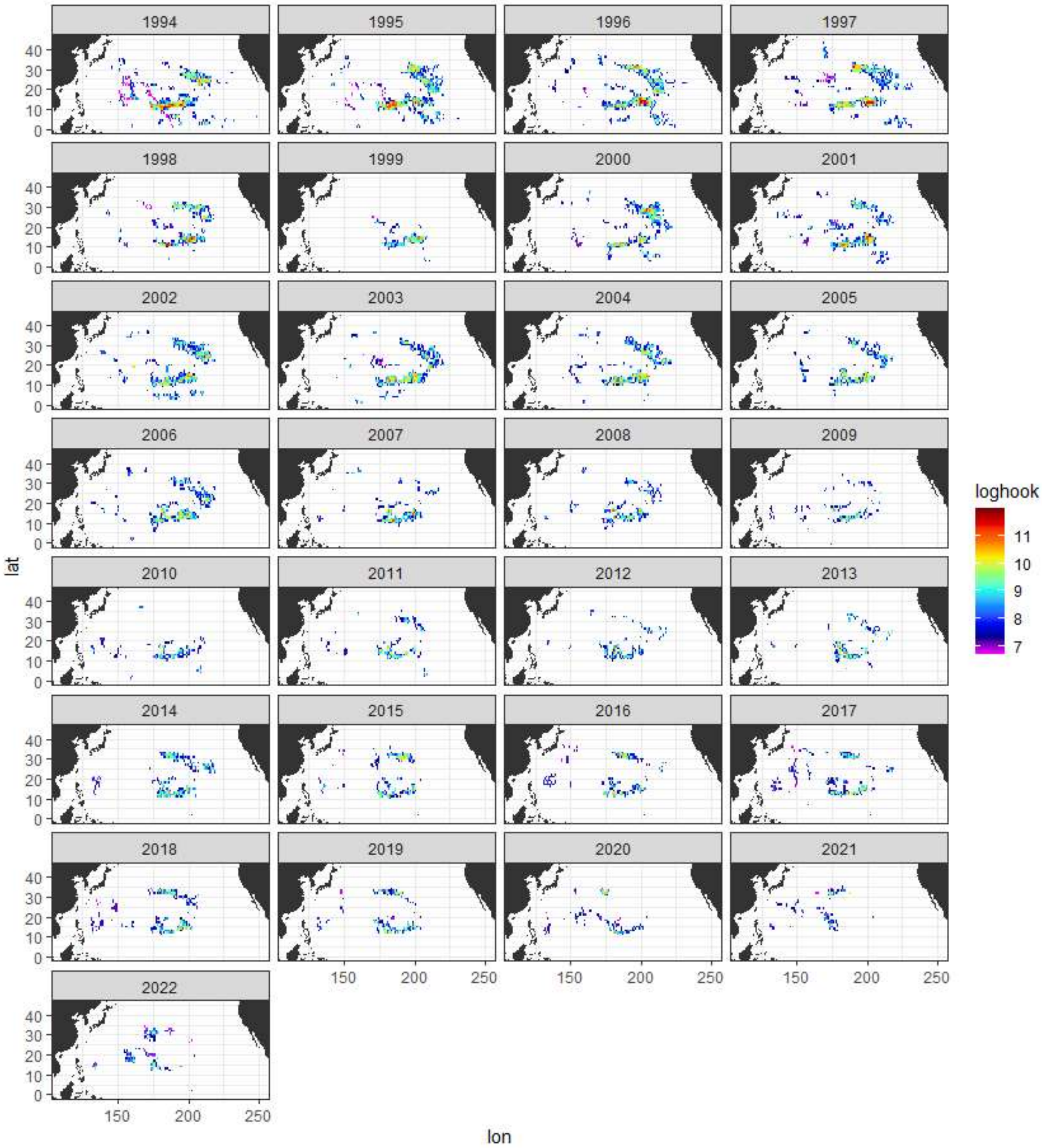

Figure 5. Year specific spatial distribution of fishing effort (total number of hooks on the logscale) used in the CPUE standardization for JRTV survey from 1994 to 2022.

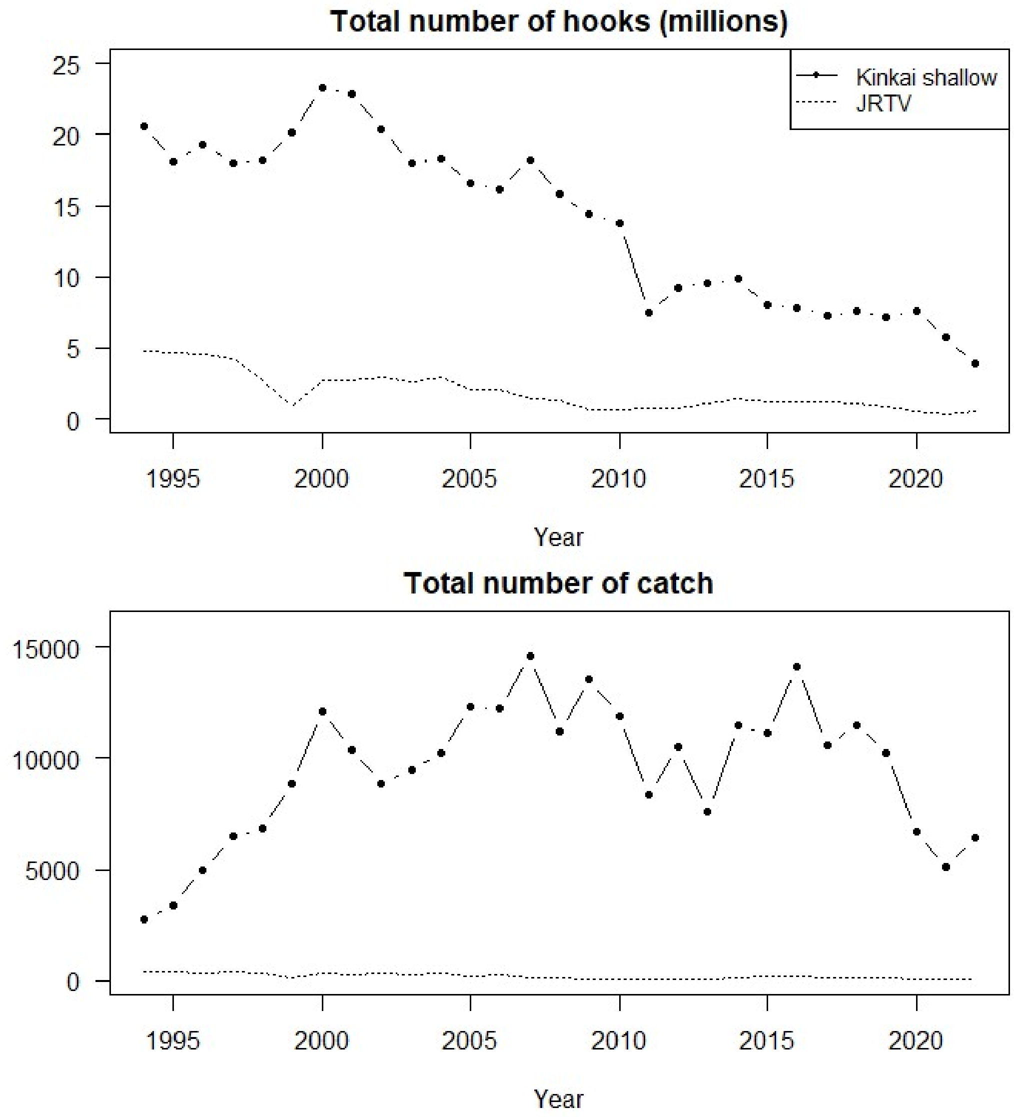

Figure 6. Annual catch in number and annual fishing effort (total number of hooks) between two Japanese CPUEs: Japanese "Kinkai shallow" longline fishery (solid line with filled circle) and JRTV survey (dotted line)

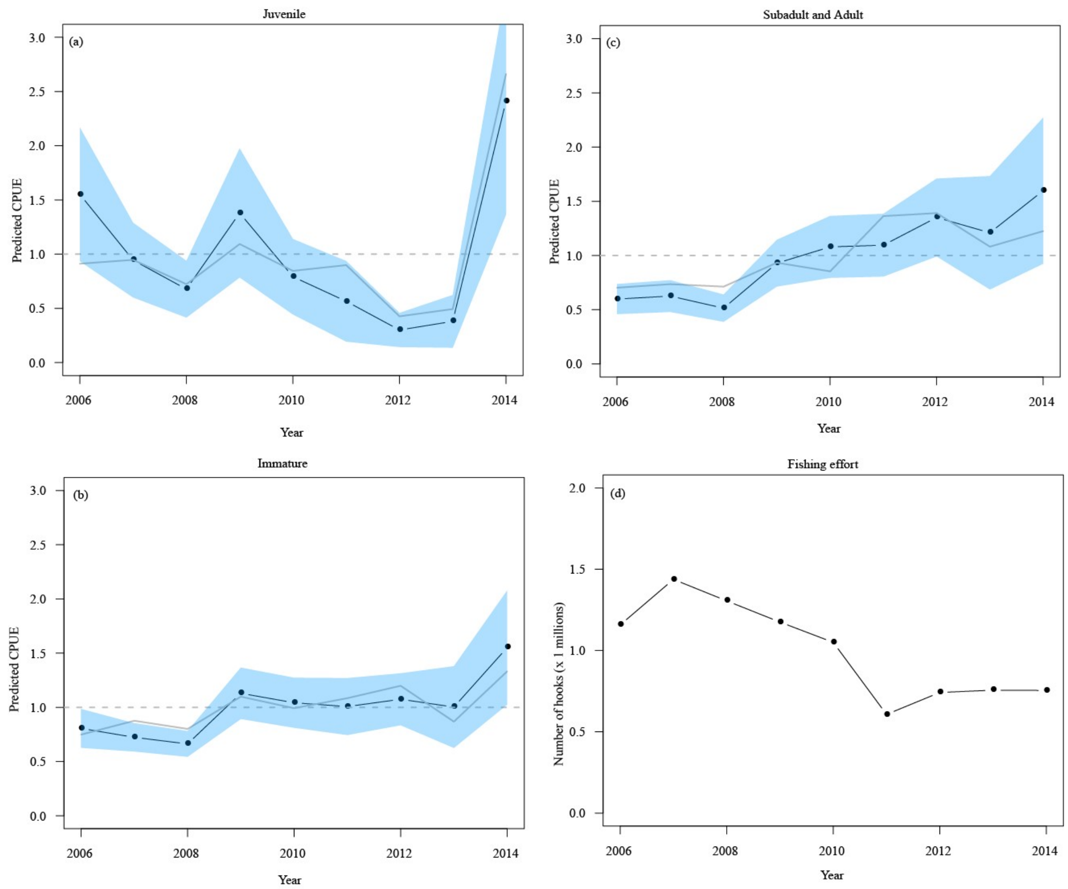

Figure 7. Referred to Kai et al. (2017). Yearly changes in predicted CPUEs relative its average (black solid line with filled circle) for three growth stages of shortfin mako :(a) Juvenile (< 100 cm PCL):(b) Immature (between 100 and 180 cm PCL) and:(c) Subadult and adult (> 181 cm PCL). Grey solid line denotes the nominal CPUE relative to its average for the three growth stages of shortfin mako, shadow denotes the 95 % confidence intervals, and the horizontal dotted line denotes mean value of relative values (1.0). We also plot the number of hooks (x 1000), representing the yearly changes of available data for shortfin mako.