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Estimation of annual catch for blue shark caught by Japanese high seas squid driftnet fishery in the North Pacific Ocean from 1981 to 1992[1]

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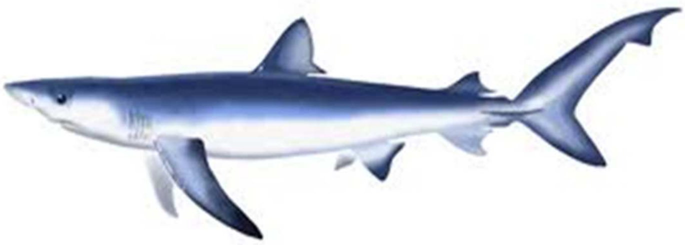

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Abstract

This working paper provided annual catches of blue shark (*Prionace glauca*) caught by Japanese high seas squid driftnet fishery in the North Pacific Ocean for 1981-1992. Since the logbook data from 1981 to 1992 have no species-specific information about sharks, the annual catches of blue shark was predicted using statistical model (a generalized linear model and a generalized additive model) with scientific observer data in 1990 and 1991 as well as the information about the logbook data from 1981 to 1992. The coefficients of explanatory variables estimated from four models (different model structures from simple to complex) with scientific observer data, and then the relevant information about factors of logbook data were used to predict the catches. The predicted catches in number of blue sharks by different models were aggregated to calculate the annual catches. The annual catches had increased since the early 1980s and peaked in 1988, and subsequently decreased sharply. Annual catches in weight converted from the catch in number using an average weight of individuals were widely ranged from 645 to 20,268 MT. We recommend that the estimated catches will be used for the upcoming stock assessment of blue sharks in the North Pacific Ocean because the estimated catches are more reasonable from the view of the annual changes in the trends compared to the unaccountable constant catches used in the previous stock assessment.

Introduction

Japanese high seas driftnet fisheries consist of "the large mesh driftnet fishery" which targeted striped marlin (*Kajikia audax*) and albacore (*Thunnus alalonga*) (Nakano et al., 1993) and "the squid driftnet fishery" which targeted flying squid (*Ommastrephes bartrami*) (Yatsu et al., 1993). The Japanese large-mesh driftnet fishery commenced the operation in the beginning of 1970s (Nakano et al. 1993) and the Japanese squid driftnet fishery commenced the operation in 1978 (Yatsu et al. 1993). A substantial number of sharks were caught by these fisheries (mainly squid driftnet fishery) as non-target species, especially blue shark, (*Prionace glauca*) in 1980s and the beginning of 1990s (McKinnell & Seki 1998). Bule sharks less than 1 m in length, caught by squid driftnet fishery, were usually discarded (Mckinnel & Seki 1998).

In the previous stock assessment of North Pacific blue shark (ISC 2017), the historical catches of blue shark caught by Japanese squid driftnet fishery from 1981 to 1992 were used. However, the annual catches had critical issues because a constant value (13,331 MT) was used as the annual catches from 1981 to 1988 and detailed information about the catches including the calculation/estimation methods was not described in the previous literatures. It is therefore necessary to clarify and update the historical catches of blue shark caught by Japanese high seas squid driftnet fishery.

Annual catches are an essential information for the stock assessment of sharks. The data coverage of logbook is high, however, the data reported by fisherman is frequently lacking a detailed information such as a species-specific name of sharks and the accuracy of the catch record for sharks is low due to an underreporting of the catch. To complement the under-reporting of logbook data, scientific observer data could be useful, though the scientific observer data have an issue of lower data coverage compared to logbook data (Yatsu et al., 1993). For example, the observer data can be used to validate the reporting rates of the logbook data and to estimate accurately the catch rates (i.e. catch per unit effort; CPUE) of blue shark. If we utilize these merits of logbook data and scientific observer data, it is possible to estimate accurately the annual catch of blue shark through multiplying the annual catch rate of observer data by the annual fishing effort collected by logbook data.

The objective of this document paper is to estimate the annual catches of blue shark caught by Japanese high seas squid driftnet fishery from 1981 to 1992 using the logbook data and scientific observer data.

Materials and methods

Data source

1. Logbook data from 1981 to 1992

This data aggregated by 10 days contains the following information: number of operations; fishing time (year and month); latitude and longitude by 1×1 degrees; fishing effort in number of "tans" per operation; and catch in weight (kg) of several species. The "tan" is a unit of net used in Japan and the standard length of one "tan" is approximately 50 m. Multiple "tans" (approximately 70-200 tans) are connected to form "section" and the driftnet used in an operation normally consists of 7-10 "sections" (Yatsu et al., 1993). The "species" comprises of the flying squid, Pacific pomfret (*Brama japonica*), sharks (no species-specific), skipjack tuna (*Katsuwonus pelamis*), yellowtail (*Seriola dumerlli*) and billfishes. The zero-catch ratio of sharks was considerably high (approximately 80%) on a basis of fishing operations for 10 days.

Since the regulation for the squid driftnet fishery (the fishing period was restricted to 7 months from June 1 to December 31 and the fishing area was restricted to 20-46^{o}N and 170^{o}E-145^{o}W) was established by Japanese government and the regulation had been enforced since 1981 (Yatsu et al., 1993), the operational area was changed seasonally from southern water (mainly 35-40^{o}N in quarter 2; May-June) to northern water (mainly 40-45^{o}N in quarters 3 and 4; July-December) (Fig. 1). In this paper, the quarters (qt) were therefore separated into two seasons of qt1 (May-June) and qt2 (July-December) in accordance with the shifts of the operational area.

The fishing effort (total length in km of "tans") was defined through multiplying the number of "tans" by length of one tan (50 m). Since there was a large discrepancy of the number of "tans" between the previous document paper (Fujinami & Kai 2018) and the past literature (Yatsu et al. 1993), we updated the number of "tans" (1986-1992) using the original logbook data because the numbers of original data were almost similar with those shown in Yatsu et al. (1993) (Table 1). For the remaining years from 1981 to 1985, we could not find any original data. Thereby, we estimated the number of "tans" during this period (1981-1985) using a mean value of ratios between previous and updated data for 1986-1988.

2. Scientific observer data from 1990 to 1991

This data contains fishing date (year, month, day, time), fishing area (latitude and longitude), environmental condition (sea surface temperature and oceanic condition) at the operational location, gear configurations (mesh size, number of "tans", length of one "tan", and number of "section") and catch in number of all species caught by the driftnet fishery. As with the logbook data, the season was separated into two quarters (Fig. 2).

Catch estimation

Catches in number of blue sharks caught by the Japanese squid driftnet fishery during 1981 and 1992 were predicted using generalized additive model (GAM) and generalized linear model (GLM) with logbook data from 1981 to 1992 and scientific observer data in 1990 and 1991. The procedures (Fig. 3) are as follows;

I. Since the zero-catch ratio of blue shark in the observer data was high (46%) and the count data was over-dispersion, negative binomial model was used for GAM and GLM. To estimate coefficients of explanatory variables in the models for different combination of factors, we used four different model structures.

$$\mathrm{Catch} \cong \mathrm{NB}(\mu, \theta)$$
$$\mathrm{Model1:} \log(\mu) = intercept + factor(qt) + s(latitude, longitude) + offset(effort) + error$$
$$\mathrm{Model\ 2:} \log(\mu) = intercept + s(latitude, longitude) + offset(effort) + error$$
$$\mathrm{Model\ 3:} \log(\mu) = intercept + factor(qt) + offset(effort) + error$$
$$\mathrm{Model\ 4:} \log(\mu) = intercept + offset(effort) + error$$

where Catch is catch in number, NB is a negative binomial model (error) with the mean μ and variance θ, the link function is log, the quarter (qt) was given as a fixed effect, the interaction of latitude and longitude was given using spline function and fishing effort was given as an offset term after transforming logarithm.

II. The models were run using the R software (version 3.3.1). Akaike Information Criterions (AIC) and Bayesian Information Criterions (BIC) were used to select the most parsimonious model from the four models. The goodness-of-fits for the best model was also investigated using the residual plots and the fitting the model to the data was evaluated. The estimated coefficients of intercept and explanatory variables (qt, and latitude and longitude) from scientific observer data and corresponding fishing effort from logbook data during 1981 to 1992 were used to predict the catches of blue shark.

III. The most parsimonious model was basically used to predict the catch. However, the remaining models were also used to predict the catch if the fishing area and/or time of logbook data was not covered by scientific observer data because the spatiotemporal coverage of logbook data was higher than that of scientific observer data. Hereafter, the best model is referred to "prediction model".

IV. The predicted catches of blue sharks from the multiple models were aggregated by year.

V. Total catches in weight of blue sharks were calculated using the predicted catch in number and a reported average weight (7.0 kg) of blue sharks caught by Japanese high seas squid driftnet fishery (Yatsu et al. 1993).

Evaluation of prediction model

Annual catches of scientific observer data in 1990 and 1991 were predicted using the prediction model with the scientific observer data to evaluate the accuracy of the prediction model. The predicted annual catches in 1990 and 1991 were compared with the observed annual catches.

Results

Eleven shark species were reported by scientific observer during 1990 and 1991. The catch of blue shark was accounted for 92.5% (*n*=91,233) and 95.4% (*n*=95,567) of the total catch for sharks in 1990 and 1991, respectively. The overall (upper figure) and quarter-specific (qts.2-4, lower figures) spatial distributions of catch in number collected by scientific observer showed that blue sharks were mainly caught in the eastern water of the operational area (37-42ºN and 150-170ºW), especially in qt 2 and qt 3 (Fig. 4).

In the comparisons among four NB models, both AIC and BIC selected the full model including qt, latitude, and longitude (Model 1 in Table 1) as the best model. In addition, the AICs and BICs of the remaining models showed that the performance of more complicated model was better than that of simpler model (Table 2).

The predicted annual catches from the prediction model in 1990 and 1991 were 104,112 and 92,695, respectively. The operation numbers of logbook data for each prediction model and its rates showed that the data with 88.0 % of operation number were applied to model 1 (qt, latitude, longitude), while there was no data used for model 4 (intercept) (Table 3).

Discussion

The predicted catches in number of blue sharks had increased since the early 1980s and peaked in 1988, and then sharply decreased (Table 4, Fig. 6). Lowest annual catch in 1981 was caused by the extremely low fishing effort in 1981 (2.5 million "tans" in 1981, 15.7-36.4 million "tans" in other years). Yatsu et al. (1993) reported that the number of deployed "tans" in the logbook data from 1978 to 1981 were unreliable; thus, the predicted catch in 1981 is probably much lower than the actual annual catch. On the other hand, the lower annual catches in 1990s were resulted from a sharp decline in the number of actual vessels operated in the offshore and high seas (Yatsu et al. 1993) that caused a substantial decrease of deployed "tans" from 34.9 million in 1989 to 22.8 million in 1990.

Compared with the annual catches of blue sharks caught by Japanese squid driftnet fishery in 1989 and 1990 calculated by Yatsu et al. (1993), the decreasing trends in the estimated annual catch were similar, however the absolute annual catch in this study was slightly higher than that reported by Yatsu et al. (1993) (Table 4). Our prediction method seems to be better than that of Yatsu (1993) because they assumed that the observer data were randomly sampled from the operations by commercial vessels. This implies that the previous study did not directly consider the spatial and temporal changes in the operations. Moreover, the previous study provided catch estimation only in 1989 and 1990, whereas our method can provide annual catches for overall period when the logbook data are available (1981-1992).

Estimated annual catches in weight using reported average weight were widely ranged from 645 to 20,268 MT for 1981-1992 (Table 4). The estimated catches in weight were largely different from those reported in the previous stock assessment for North Pacific blue sharks (ISC 2017) because a constant value (13,331 MT) was used as the annual catches of blue shark from 1981 to 1988. We recommend using the estimated catches in this paper for the upcoming stock assessment of blue sharks in the North Pacific Ocean because the values are more reasonable from the view of the annual changes in the tends compared to the unaccountable constant values used in the previous stock assessment.

Acknowledgements

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Nakano, H., Okada, K., Watanabe, Y., Uosaki, K. (1993). Outline of the large-mesh driftnet fishery of Japan. Int. N. Pac. Fish. Comm. Bull. 53: 25-37.

Yatsu, A., Hiramatsu, K., Hayase, S. (1993). Outline of Japanese squid driftnet fishery with notes on the by-catch. Int. N. Pac. Fish. Comm. Bull. 53: 5-24.

Table 1. Annual number of “tans” in Japanese high seas squid driftnet fishery in the North Pacific Ocean reported by Yatsu et al. (1993), Fujinami & Kai (2018), and this study. Updated number of “tans” of original logbook data shows dark gray colors, and estimated number of “tans” using a mean value of ratios between previous data (Fujinami & Kai 2018) and updated data for 1986-1988 shows light gray colors.

Year	Deployed number of “tans”		
	Yatsu et al. 1993	Fujinami & Kai 2018	Updated data
1978	NA	NA	NA
1979	NA	NA	NA
1980	NA	NA	NA
1981	NA	1957778	2485748
1982	21928768	18945125	24054209
1983	25224746	20621759	26182995
1984	29251829	24141707	30652195
1985	34023355	28041220	35603321
1986	36367294	28086786	36425751
1987	32017130	25261562	32004070
1988	36055567	28989518	36112758
1989	34385032	33435581	34859449
1990	22769857	22697528	22754520
1991	NA	21671752	22083135
1992	NA	15656091	15651839

Table 2. AIC and BIC for four negative binomial models.

Model	Added explanatory variables	AIC	BIC
1	+ qt+ latitude + longitude	157695.5	157965.9
2	+ latitude + longitude	157975.8	158237.8
3	+ qt	164867.9	164893.4
4	Intercept	165739.5	165756.4

Table 3. Operation numbers of logbook data for each prediction model and its rates.

Model	Model 1 (qt, latitude, longitude)	Model 2 (latitude, longitude)	Model 3 (qt)	Model 4 (Intercept)
Number	282,215	11,480	16,842	0
Rate (%)	88.0	3.6	8.4	0.0

Table 4. Estimated catches in number and weight (MT) of blue sharks caught by the Japanese high seas squid drift from 1981 to 1992.

Year	Catch in number		Catch in weight (MT)	
	This study	Yatsu et al. 1993	This study	Stock assessment in 2017
1981	92196	-	645.4	13331.3
1982	1222967	-	8560.8	13331.3
1983	1669499	-	11686.5	13331.3
1984	2030854	-	14216.0	13331.3
1985	2240826	-	15685.8	13331.3
1986	2453425	-	17174.0	13331.3
1987	2213408	-	15493.9	13331.3
1988	2895420	-	20267.9	13331.3
1989	2224527	1439581	15571.7	20022.0
1990	1036736	723933	7257.2	8758.4
1991	942915	-	6600.4	8758.4
1992	654547	-	4581.8	4379.2

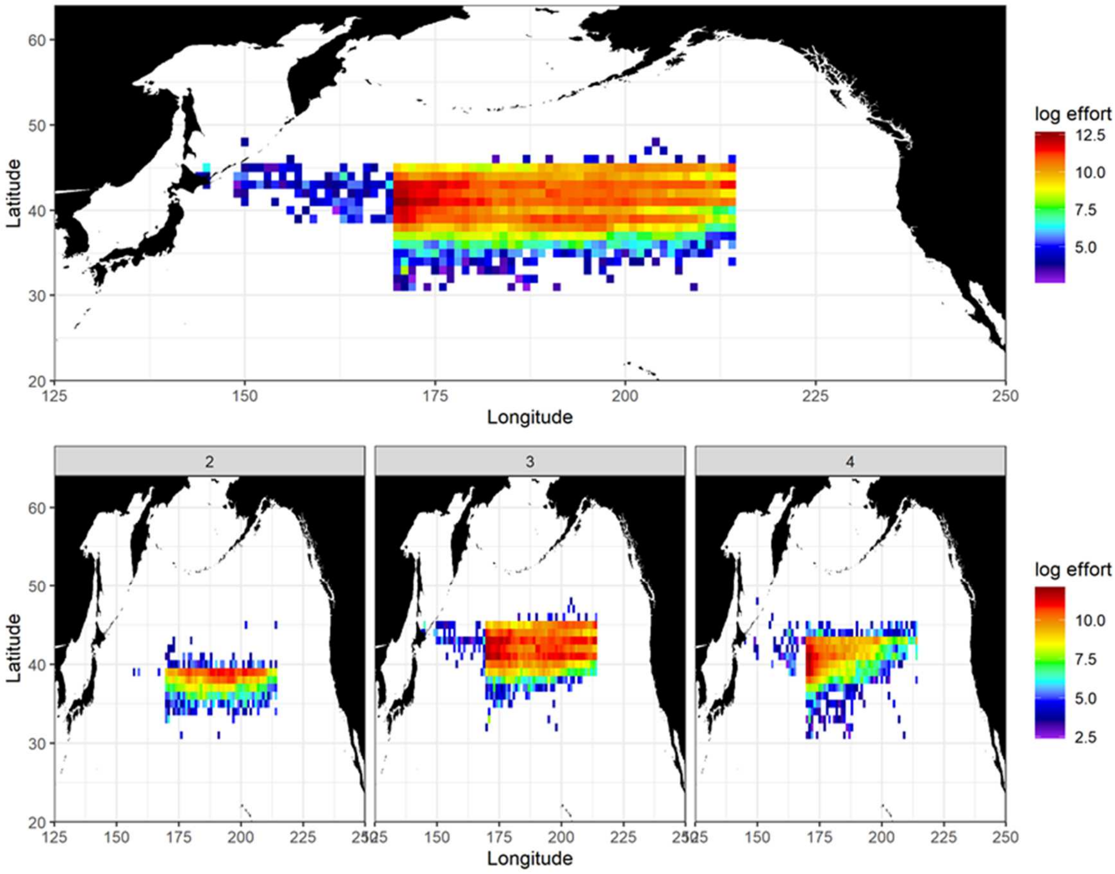

Fig. 1. Spatial distribution of log transformed fishing effort for the Japanese high seas squid driftnet fishery using overall (upper figure) and quarter-specific (qts.2-4, lower figures) logbook data collected from 1981 to 1992.

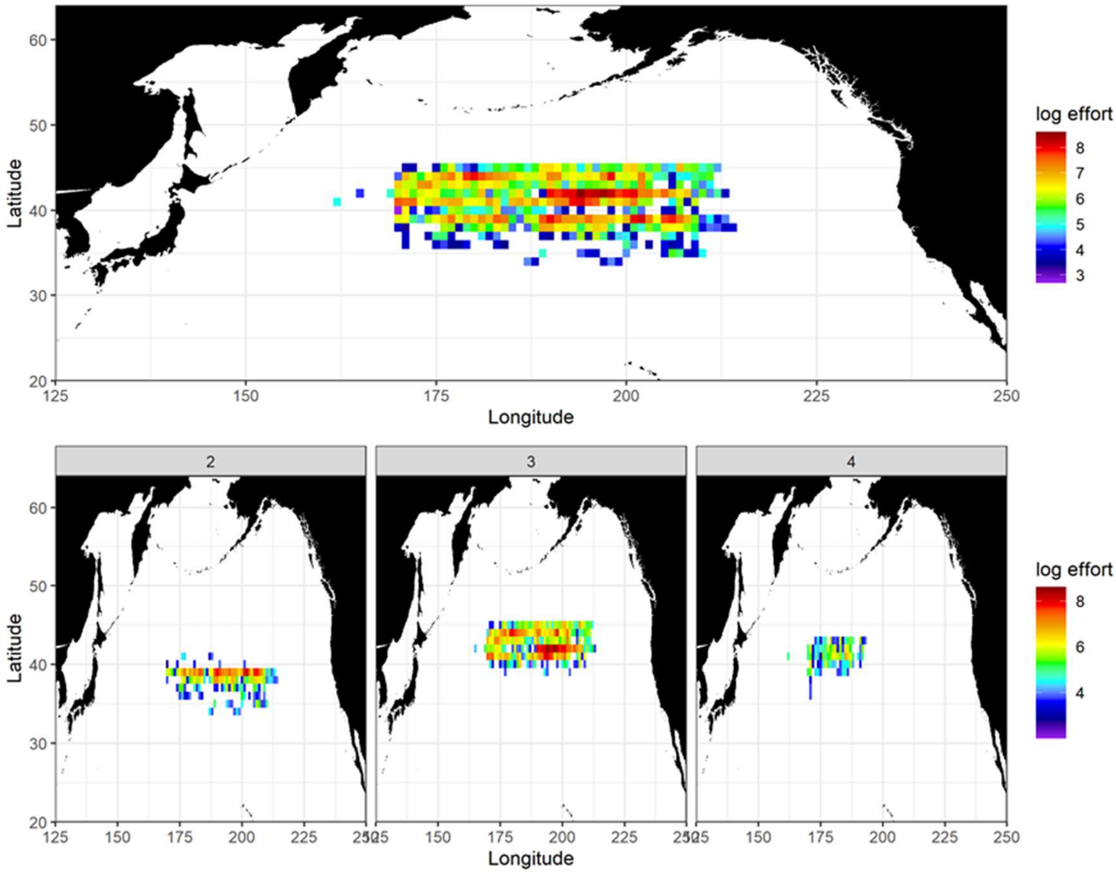

Fig. 2. Spatial distribution of log transformed fishing effort for the Japanese high seas squid driftnet fishery using overall (upper figure) and quarter-specific (qts.2-4, lower figures) scientific observer data collected in 1990 and 1991.

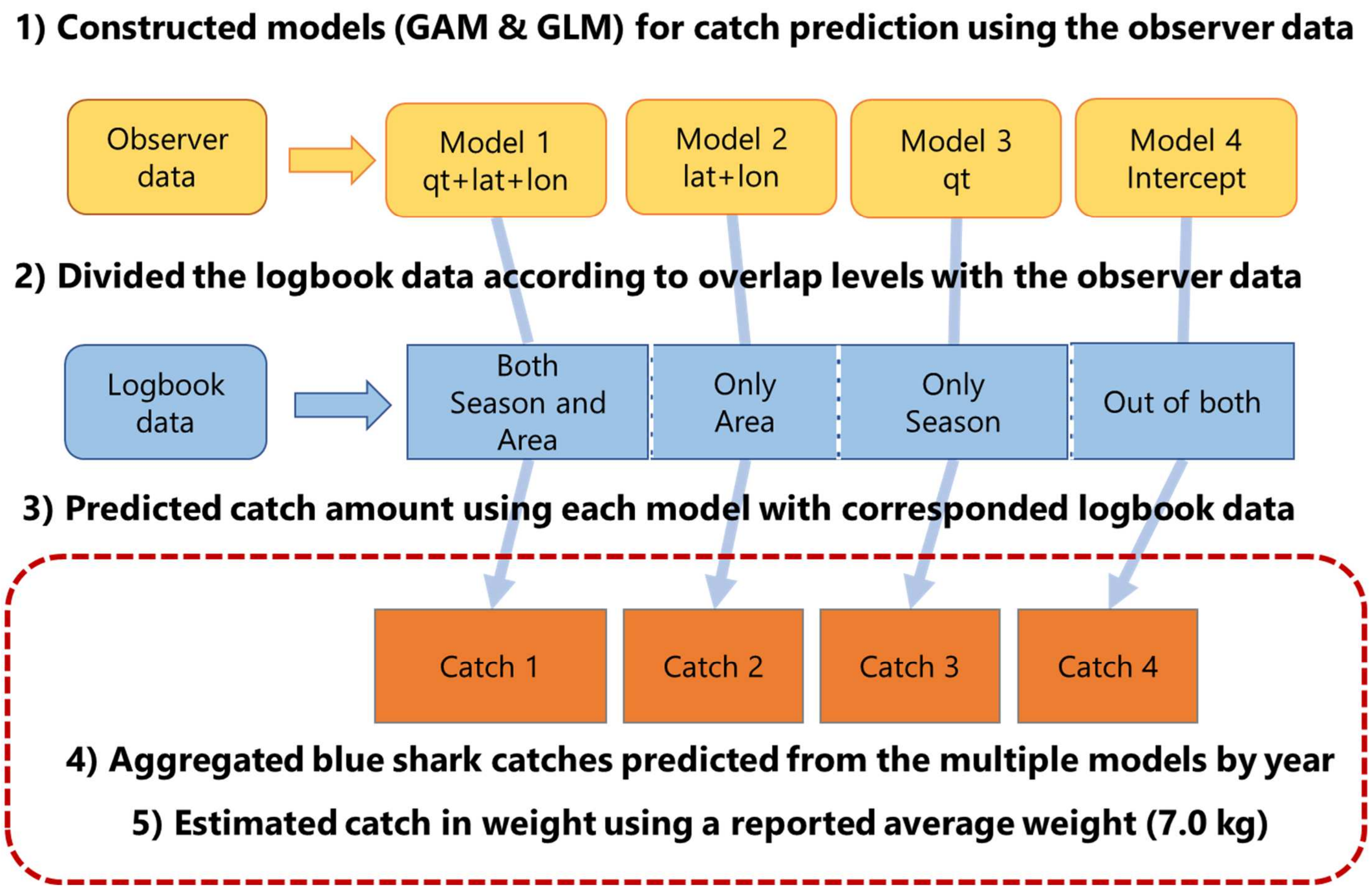

Fig. 3. Procedures of catch prediction for blue shark (*Prionace glauca*) caught by the Japanese high seas squid driftnet fishery.

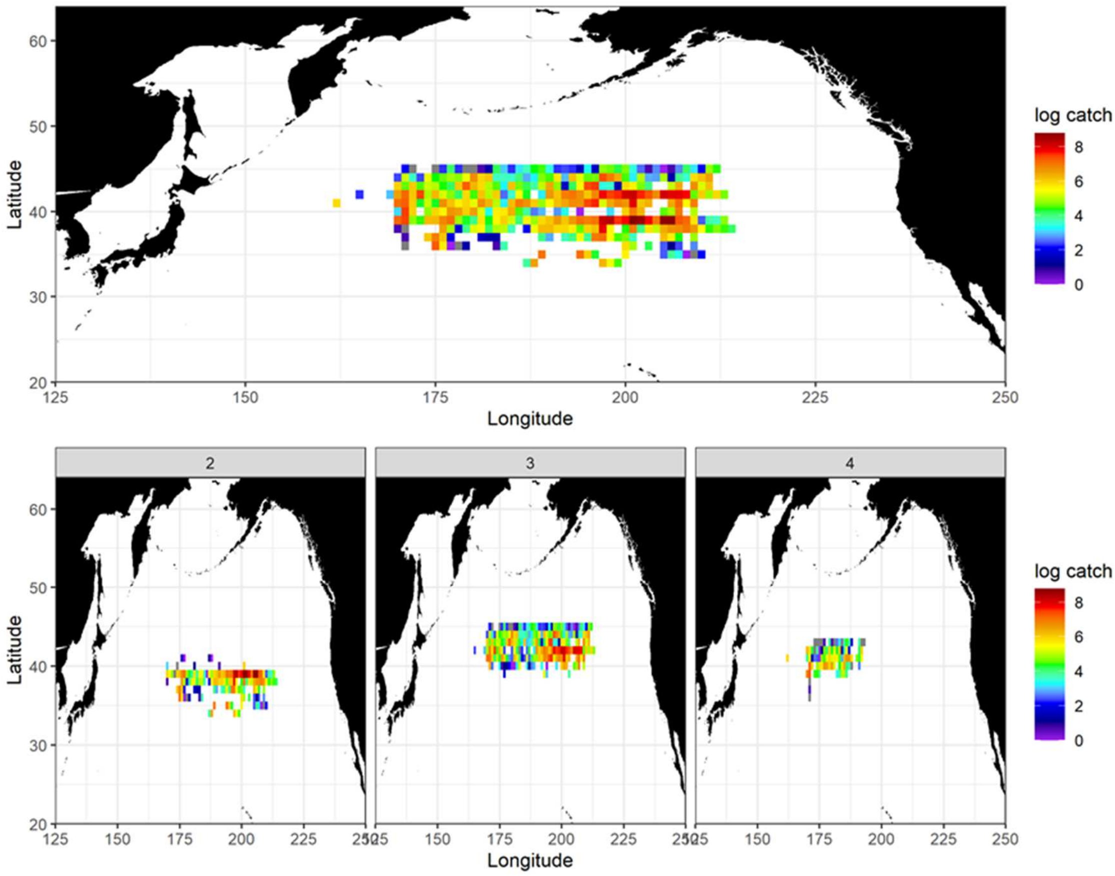

Fig. 4. Spatial distribution of log transformed blue shark catches in number for the Japanese high seas squid driftnet fishery using overall (upper figure) and quarter-specific (qts.2-4, lower figures) scientific observer data collected in 1990 and 1991.

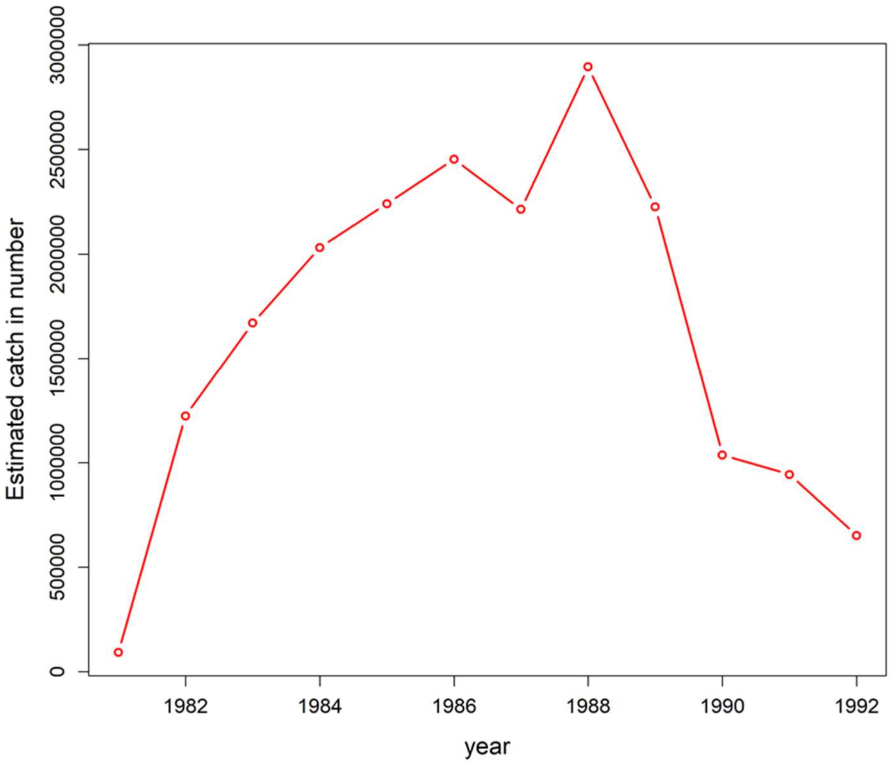

Fig. 6. Estimated catches in number of blue sharks caught by the Japanese high seas squid driftnet fishery from 1981 to 1992.

Appendix: Summary of goodness-of-fits for the outputs of GAM analyses from R

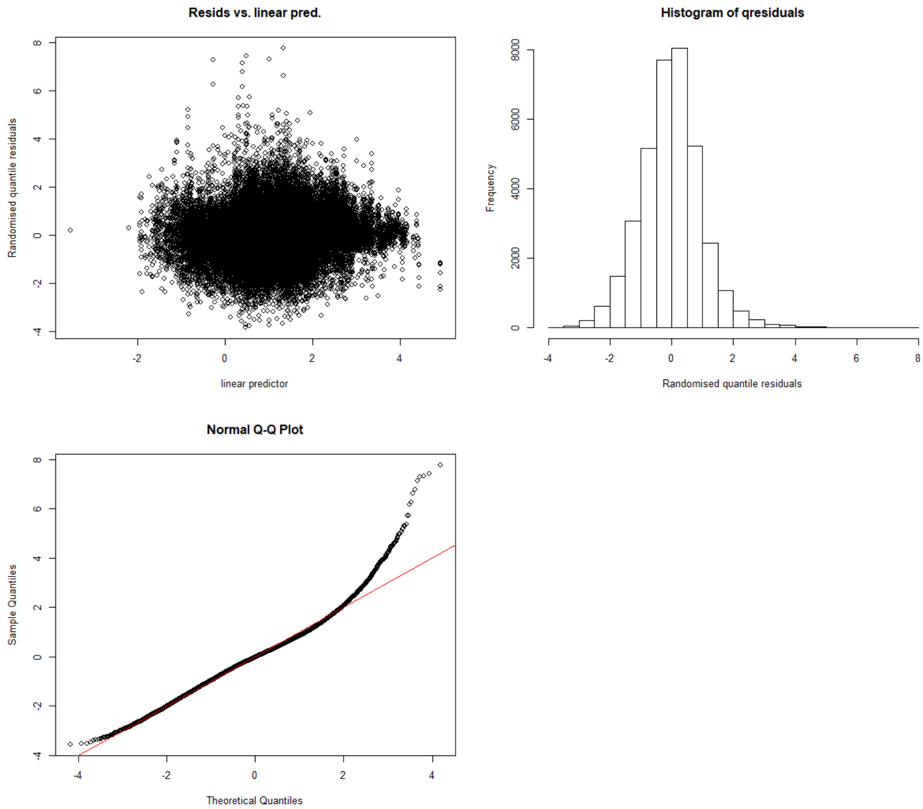

Fig. A1. Diagnostics of the goodness-of-fits for the best model with negative binomial error distribution from the GAM analysis.

Family: Negative Binomial (0.328)

Link function: log

Formula:

t. catch.102 ~ factor(qt) + s (Lon, Lat) + offset(log(effort))

Parametric coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-8.35769	0.04025	-207.65	<2e-16	***
factor(qt)3	1.07483	0.05399	19.91	<2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:

	edf	Ref.df	Chi.sq	p-value	
s(Lon,Lat)	28.81	29	8328	<2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) = 0.0649 Deviance explained = 22.3%

-REML = 78948 Scale est. = 1 n = 35968

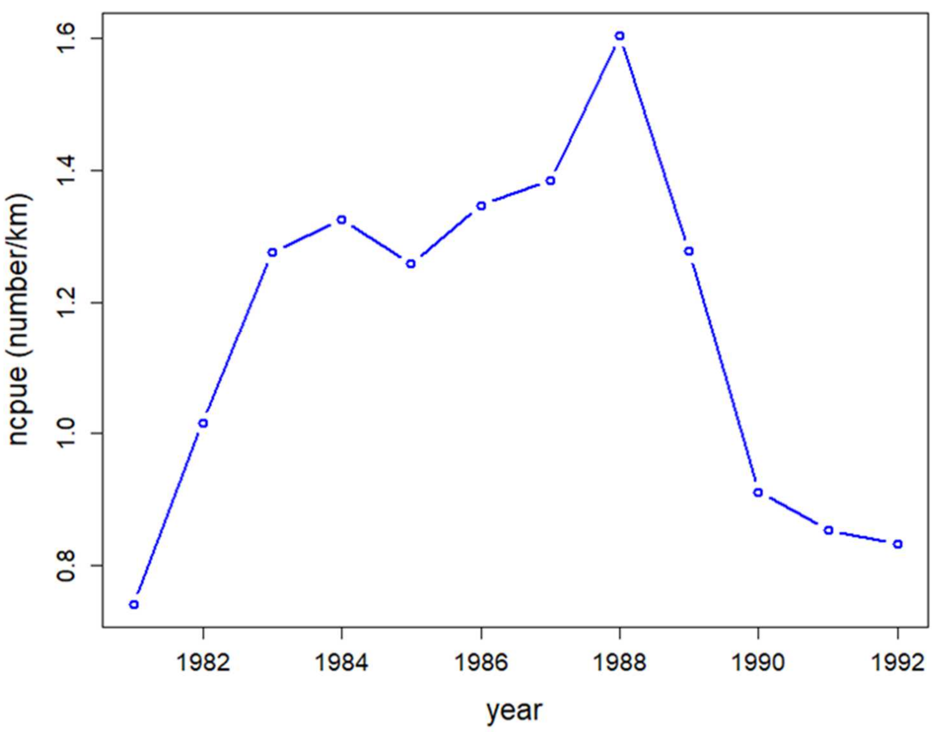

Fig.A2. Nominal CPUE (catches in number / km) for blue sharks caught by Japanese high seas squid driftnet fishery from 1981 to 1992.