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CPUE and catch of shortfin mako caught by Japanese shallow-set longliner in the western North Pacific[1]

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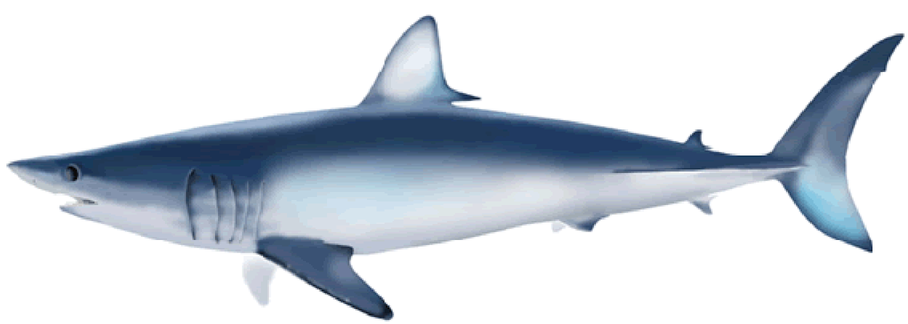

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Abstract

This working paper provides with the estimation of catch per unit of effort (CPUE) and catch of shortfin mako, *Isurus oxyrinchus*, caught by Japanese shallow-set longliner during 1994 to 2013 in the western North Pacific. Two filtering methods were applied to choose the reliable vessels using the data in 2000s. Filtering (I) is conducted based on the AIC estimated from CPUE standardization, in comparison between longline research vessel and commercial vessel. Filtering (II) is conducted based on the visual observations of the positive catch of shortfin mako for each vessel. Area was separated into four areas using GLM tree. Negative binomial model was used to standardize the CPUE for filtered data from 1994 to 2013. Four different models (three area model, four area model, five area model, and no area model) were applied, and the four area model was selected by AIC. The estimated abundance indices showed an increasing trend. These CPUE series represent the abundance indices of juvenile and sub-adults (60-200 cm PCL) in the western North Pacific (25-45 N and 137 E-160 W). Also, the catch number was estimated by multiplication of the CPUE by total effort of Japanese shallow-set fishery in the western North Pacific. The number was converted by the average weight. The estimated and retained catch weight (tons) had slightly increased until around 2006 and has been slightly decreasing due to the decreasing of the effort.

Introduction

The previous working document paper presented the abundance indices of Japanese longline fisheries (Kai *et al*. 2014a). However three issues were mainly raised by the ISC shark working group (ISC 2014) as follows: (1) shallow-set and deep-set were not separated though these fishery targets the different species: (2) the inconsistent trends of CPUE between the analysis and the one on the fishery-independent survey (Ohshimo *et al*. 2014): (3) the area stratification chosen in the analysis was based on that used for blue shark. Based on these issues, the improvements of the analyses were recommended as follows: (i) nominal CPUE calculated for smaller areas could be examined: (ii) the data be divided into several subsets: (iii) improvement of the area stratification: (iv) validation of the data using training vessel and research data.

The purposes of this document paper are to improve the analyses based on the recommendations by ISC shark WG and to estimate the reliable standardized CPUE and catch for1994-2013. In this document paper, we focused on the Japanese shallow-set fishery.

Materials and Methods

Data Source

Set-by-set logbook data from Japanese offshore and distant water longline fishery are used to estimate the standardized CPUE and the catch for 1994-2013. The details of these data sources are described in the previous working paper (Kai *et al*. 2014). Also, skipper's note, which is the detailed records of the operation, recorded by fishermen was used to validate the reliability of the logbook's weight data.

Data Filtering

Filtering was used for the logbook data to remove the mis-reporting data. The vessels were selected by the size (20~150 vessel tonnage) and the registered prefectures ("Tohoku and Hokkaido"). The data was also chosen by the number of hooks per baskets (HPB; 3~5) to select a shallow-set fishery. These filtering process are to select data of cruise of shallow sets conducted by longline boats belongs to the association of Kesennuma offshore longline skippers and radio-operators. In addition, we conducted two additional filtering to select out the data of cruise which had apparent discards of shortfin mako shark. Filtering (I): similar trends of CPUE to those estimated from the longline research vessel by Ohshimo *et al*. (2014) were selected as follows: (1) the same condition's data with the research vessel as to the periods (April to June for 2000, 2002-2013), area (25-40° N, 140-150° E), depth (3-5 HPB) was selected from the logbook (commercial) data: (2) data of commercial and research vessels were combined, we refer these two types of data to "Other type" and "Taikei type", respectively: (3) standardized the CPUE using the combined data with incorporation of the factor of two vessel types as explanatory variable in the negative binomial model (catch = year + type +offset (hook) + error): (4) calculated the AIC: (5) randomly picked up one vessel from the vessels of "Other type" without replication and the name was changed into "Taikei type" : (6) conduct the (3) and (4) again: (7) compare the first AIC and second AIC: (8) If first AIC is larger than second AIC, the commercial data is regarded as "Taikei type", while first AIC is smaller, the commercial data is regarded as "Other type": (9) reset the name from "Taikei type" to "Other type" for the commercial data: (10) repeat (5)~(9) for all commercial vessels. Filtering (II): The data of 19 vessels were selected from 29 based on the visual observation of CPUE pattern of each set of shortfin mako shark in the past. If data contrasts of the positive catch among cruises were not clearly observed in a temporal scale, we regarded that the vessel had no misreporting and there is no specific bias for the reporting.

(Appendix Fig A.1). If the unnatural low CPUE were detected in the past cruise, the data of such longline boats were not used in the CPUE analysis as the boat not retained all their catch of shortfin mako shark. The market price of fresh shortfin mako sharks is rather low (less than 50 yen per kiro) at whole sale auction in Kesennuma fishing port and some offshore surface longliners not retained all their shortfin mako shark catch (the association of Kessennuma offshore longline skippers and radio-operators, personal comm.).

CPUE standardization

Standardized CPUE for 1994-2013 was estimated using the generalized linear model (GLM) with logbook data after only filtering by HPB, vessel tonnage, prefecture, and vessels name. Firstly, we used the delta lognormal model with the filtered data for the same periods (April to June for 2000, 2002-2013), area (25-40° N, 140-150° E), and depth (3-5 HPB) to compare with the CPUE of the research data (Oshimo *et al*. 2014). Secondly, area stratification was statistically determined by the GLM tree (Ichinokawa and Brodziak 2010) with a simple log-normal model as follows:

Log (nominal CPUE + constant) = Year + Quarter + Year* Quarter + Error, where constant was calculated from minimum value of the positive nominal CPUE. The model run was forced to stop if the area was divided into five area. Three, four, and five divided areas were used as candidate of explanatory variables of GLM. Finally, four negative binomial models were used for the CPUE standardization as follows:

Model 1: Log (Catch) = Year + Quarter + Area3 + offset (log (hook)) + 3 interaction + Error
Model 2: Log (Catch) = Year + Quarter + Area4 + offset (log (hook)) + 3 interactions + Error
Model 3: Log (Catch) = Year + Quarter + Area5 + offset (log (hook)) + 2 interactions + Error
Model 4: Log (Catch) = Year + Quarter + lat5 + lon5 +offset (log (hook)) + 1 interaction + Error

where “Catch”: expected catch number of shortfin mako, “Year”: 1994-2013, “Quarter”: 1-4, “Area-3”, “Area4” and “Area5”: three, four and five divided areas, “hook”: the number of hooks, “3interaction”: interaction terms of year*quarter, year*area, and quarter*area, “2interaction”: interaction terms of year*quarter and year*area, “1interaction”: interaction terms of year*quarter, “lat5” and “lon5”: the resolution of the latitude and longitude by 5×5 degree, “Error”: negative binomial error distribution with a log link function. The best model was selected using the AIC and Bayesian information criterion (BIC). The goodness of fit was examined using the residual patterns of GLMs. The deviance analysis of explanatory variables is also conducted to check the effects of each factor on the fitting.

Catch estimation

Catch number was estimated using the multiplication of the CPUE by total fishing effort (number of hooks) of Japanese shallow-set fishery in the western North Pacific. Catch number was multiplied by the mean body weight (kg) which was calculated from the information of catch number and processed weight of logbook data (Fig. 1). The same shallow-set data as used in the CPUE standardization was used for the calculation of the body weight. After removing the 0 kg data, the sum of processed weight was divided by the total catch number in each area. The catch weight was multiplied by conversion factor (1.298) from processed weight (headed and gutted body with fins; it is called “Kesennuma dress”) to round weight. The conversion factor was calculated using a simple linear regression with a small number of size samples (23 individuals) collected from commercial fishermen (21 individuals) and research training vessels (2 individuals). If one of the Model 1-3 was selected, the calculations above were conducted for different areas and annual catch was estimated by summing up the data by areas. Alternately, if Model 4 was chose, there is no need to consider the area-weighting.

Results

Data Filtering

Filtering (I) selected 29 vessels from 52 vessels, and Filtering (II) selected 19 vessels. The trends of standardized CPUE were not largely different between research data and logbook data, but the values of the CPUEs for logbook data were higher and lower than those for research data by year (Fig. 2, Table 1).

The mean ratio of CPUE for logbook data to that for research data was 1.41. There were similar trends of CPUE between datasets of filtering methods (I) and (II).

CPUE standardization

GLM tree separated the area into five (Fig. 3). The stratification seems to be reasonable because 30°N and 38 °N mean the border of different temperature zone, 170 °E means the edge of the Kuroshio extension, and 2nd area is a main fishing area of the blue shark and swordfish for Japanese shallow-set longliner (Kai *et al*. 2014b). As the results of model selection by AIC and BIC (Table 2), "Model 2" was selected and the operational area was divided into four small areas (lower-left panel in Fig. 3). The relative weight of area size was as follows: Area1=1.30, Area2=0.53, Area3=1.53, Area4=0.63. The fitting of the best model was good from QQ plot (Appendix Fig. A2). The deviance analysis (Table 4) indicated that all explanatory variables were significant ($p < 0.05$). Because the Model 2 includes year*area interaction term, the nominal and estimated CPUE by the four areas were weighted by the mean relative size of areas. The yearly changes of standardized CPUEs for four areas showed an increasing trend and the standardized CPUE in area 3 was the highest through the periods because of the high area weighting (Fig. 4). The yearly changes of standardized CPUEs averaged by four areas showed an increasing trend (Fig.5). These CPUE series represent the abundance indices of juvenile and sub-adults (60-200 cm PCL) in the western North Pacific (25-45 N and 137 E-160 W).

Catch estimation

The estimated catch weight (tons) and retained catch weight (tons) had increased two or three times until around 2006 and has been slightly decreasing (Table 4, Fig. 6). The decreasing trends of the catch after 2006 were caused by the decreasing trends of the effort (Kai *et al*. 2014a).

Discussions

Data filtering was conducted using new two methods, and fishing area was divided into four areas. The stratification of the area seems to be reasonable because 30°N and 38 °N are the border of different temperature zone and 170 °E is the edge of the Kuroshio extension. As the results of the filtering and area stratification, nominal CPUE calculated for smaller areas was examined and the logbook data was divided into several subsets. In addition, the trends of CPUE were compared between logbook data and research data. These are recommendations by ISC shark WG, and all of them were finished without CPUE and catch estimation of deep-set. It will be future work.

Contrary to expectation, the mean ratio of CPUE for logbook data to that for research data was higher. The research cruise is designed to cover wide areas equally, however, commercial vessel has a characteristics to gather in the higher concentration areas of the fish that results in the increase of the catch rate. The phenomenon is called "hyperstability" (Hilborn and Walters, 1992) and is viewed as a problem of CPUE. However, the issue was reduced through the CPUE standardization in consideration of the year and area interaction effects.

The juvenile shortfin mako locate their habitat in the Kuroshio-Oyashio transition zone (Kai *et al*. 2015) where it is known to have relatively higher productivity of plankton in the pelagic area (Takahashi *et al*. 2008). The transition zone contains the “Taikei” area (25-40 °N, 140-150 °E). The fishing operational areas are dependent on the positions of the transition zone and largely changed by the year and season. It is also occasionally observed that a large number of juvenile shortfin mako less than 100 cm PCL are caught by one operation in the “Taikei” area, according to the fishermen of “Kesennuma”. Probably, juvenile shortfin mako tends to form a school in the regions. These facts suggests that the higher annual catch rates of commercial fishery than those of research vessel are possible.

One of the fundamental issues of the data analyses of shark species is reliability of data sources because of the non-report and discard are frequently occurred. To remove such a biased effect, two filtering methods were introduced in this analyses and chose reliable vessels. The datasets used in this analyses are therefore considered to be reliable.

Main fishing ports of the Japanese longliner targeting for sharks were damaged by the Great East Japan earthquake and tsunami in March 11, 2011 and their operational pattern was changed. However, there was no large differences of positive catch ratios for the selected vessels before and after disaster in March 2011 (Appendix Fig. A3). Therefore, the period was not separated into two.

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Tables

Table 1. Comparisons of the standardized CPUE between logbook data filtered by filtering (II) and research data in the "Taikei" area and the ratio of the CPUE.

Year	Logbook	Research	Ratio to research
2000	0.861	0.412	2.092
2002	0.507	1.039	0.488
2003	0.887	1.027	0.864
2004	0.903	1.116	0.809
2005	1.786	0.538	3.323
2006	1.993	0.680	2.932
2007	1.265	0.914	1.384
2008	1.457	1.020	1.429
2009	2.915	1.665	1.750
2010	1.946	1.042	1.869
2012	1.369	1.034	1.324
2013	0.635	1.267	0.501

Table 2. AIC and BIC of four models for the results of CPUE standardization using logbook data of shortfin mako for 1994-2013.

	Model-1 (5 area)	Model-2 (4 area)	Model-3 (3 area)	Model-4 (no area)
AIC	111,917	111,452	111,714	112,045
BIC	113,244	112,689	112,761	112,853

Table 3. Deviance analysis of explanatory variables for the generalized linear model that describes the variability of CPUE.

Factors	LR Chisq	Df	Pr(>Chisq)
Year	1715	19	0.001 < 0
Quartor	9	3	0.025
Area	1365	3	0.001 < 0
Year*Area	435	57	0.001 < 0
Year*Area	427	57	0.001 < 0
Quarter*Area	540	9	0.001 < 0

Table 4. Retained and estimated Japanese shallow-set total retained and estimated catch number ans weight (kg) of Western North Pacific shortfin mako shark in weight (tons). Shaded values denotes that the estimated catch is smaller than the retained catch.

Year	Retained Catch Number	Estimated Catch Number	Retained Catch Weight (ton)	Estimated Catch Weight (ton)
1994	3060	6920	129	301
1995	3457	7940	157	365
1996	4759	8148	212	364
1997	6245	7818	240	322
1998	6704	8970	307	424
1999	8596	9738	389	460
2000	11783	11301	434	442
2001	10506	10212	374	394
2002	9031	9234	352	391
2003	9637	11343	334	432
2004	9803	11290	339	422
2005	12198	13879	407	489
2006	11602	14464	456	610
2007	14389	14945	538	581
2008	12083	11302	431	421
2009	15159	13892	482	486
2010	12836	12283	431	482
2011	9174	9420	369	418
2012	11191	10604	461	470
2013	7512	9005	343	448

Figures

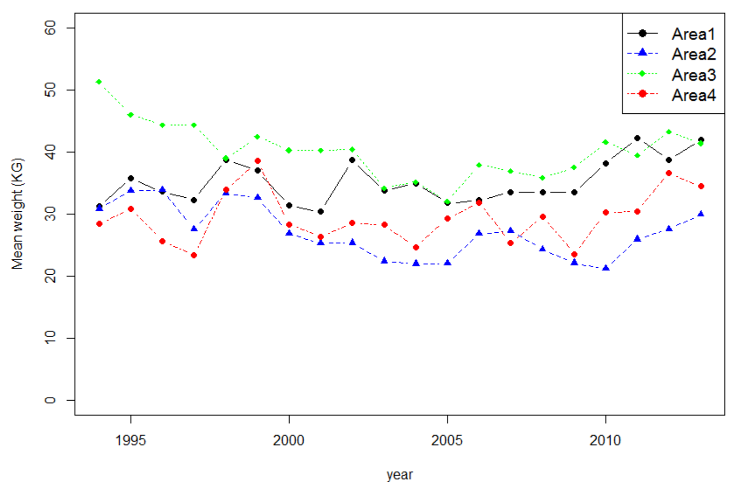


Figure 1. Mean processed body weight (kg) of shortfin mako by four areas.

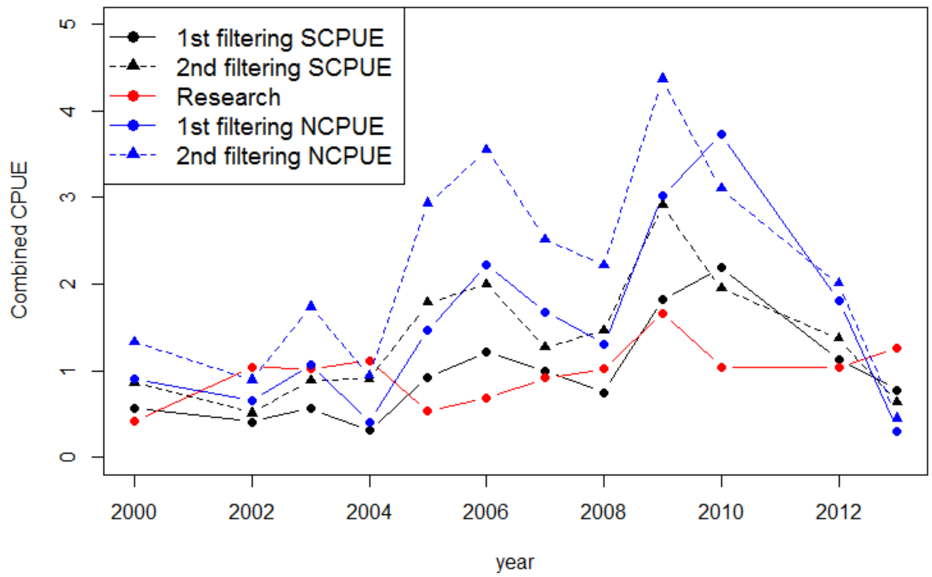


Figure 2. Yearly changes of nominal CPUE (blue lines) and standardized CPUE among research data (red line) and logbook data filtered by filtering methods (I) and (II) (black lines).

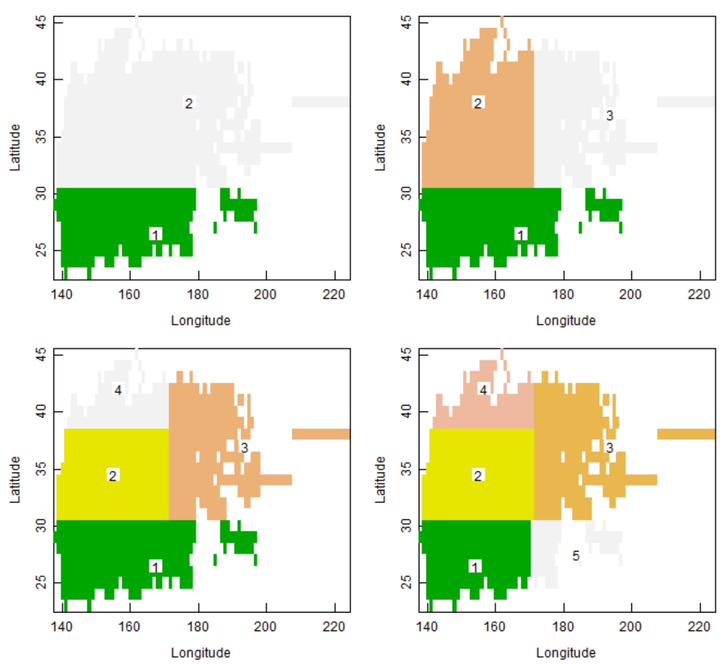


Figure 3. Area stratification by GLM tree for the data filtered by filtering method (II).

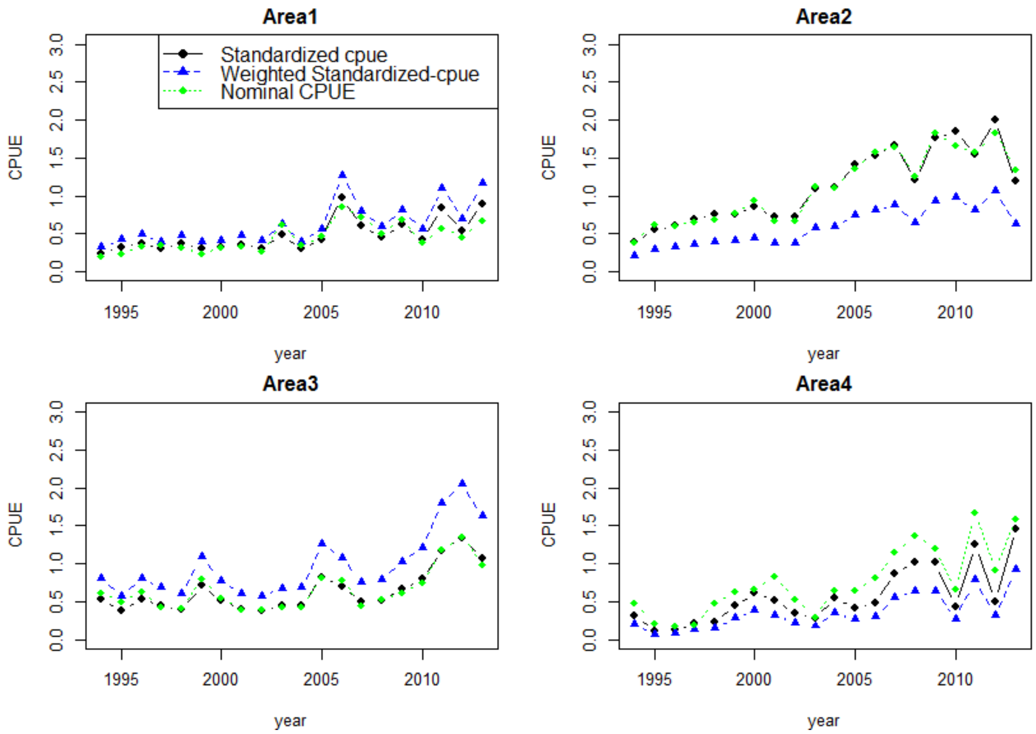


Figure 4. Yearly changes of weighted nominal CPUE (green lines), standardized CPUE (black lines), and weighted standardized CPUE by area (blue lines) for four areas.

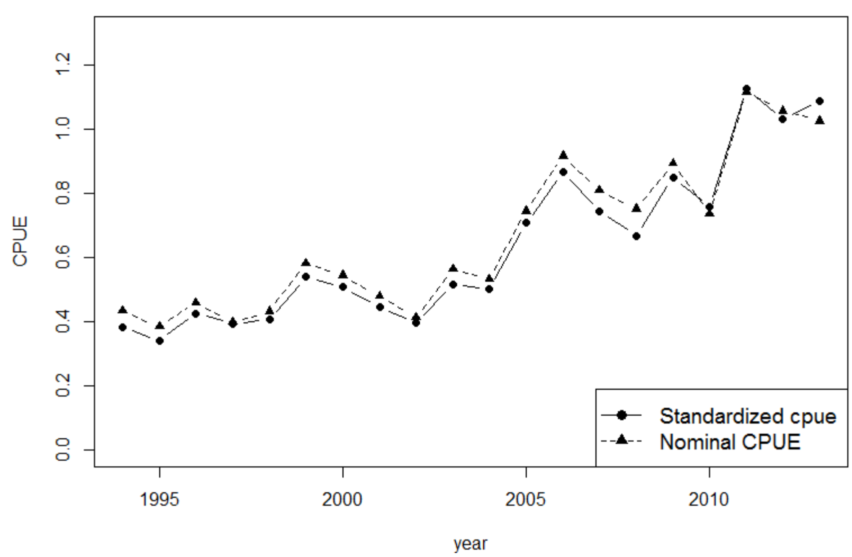


Figure 5. Yearly changes of nominal CPUE (broken line with triangle) and standardized CPUE (solid line with filled circle).

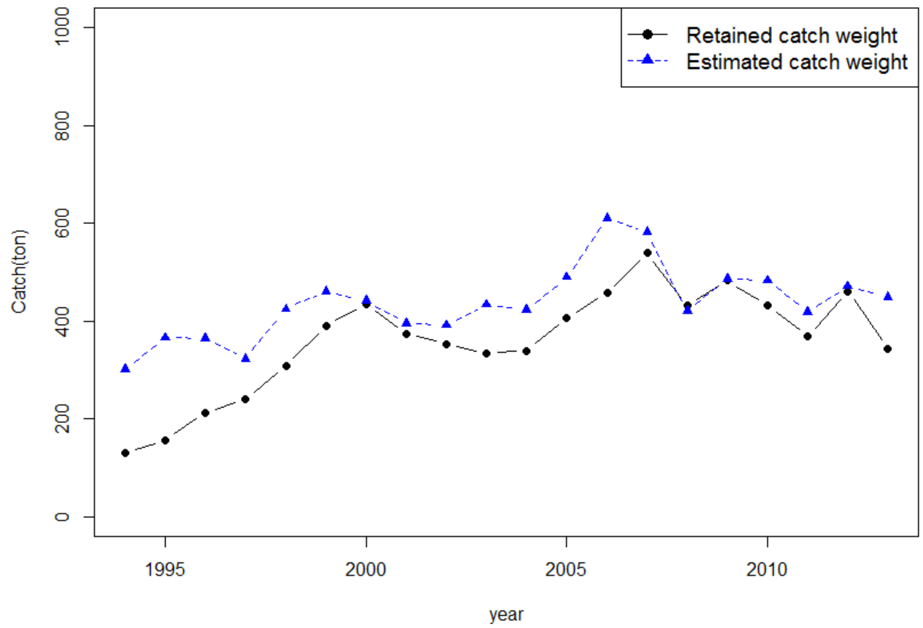


Figure.6 Retained and estimated Japanese shallow-set total retained and estimated catch weight (ton) of Western North Pacific shortfin mako shark in weight (tons).

Appendix Figures

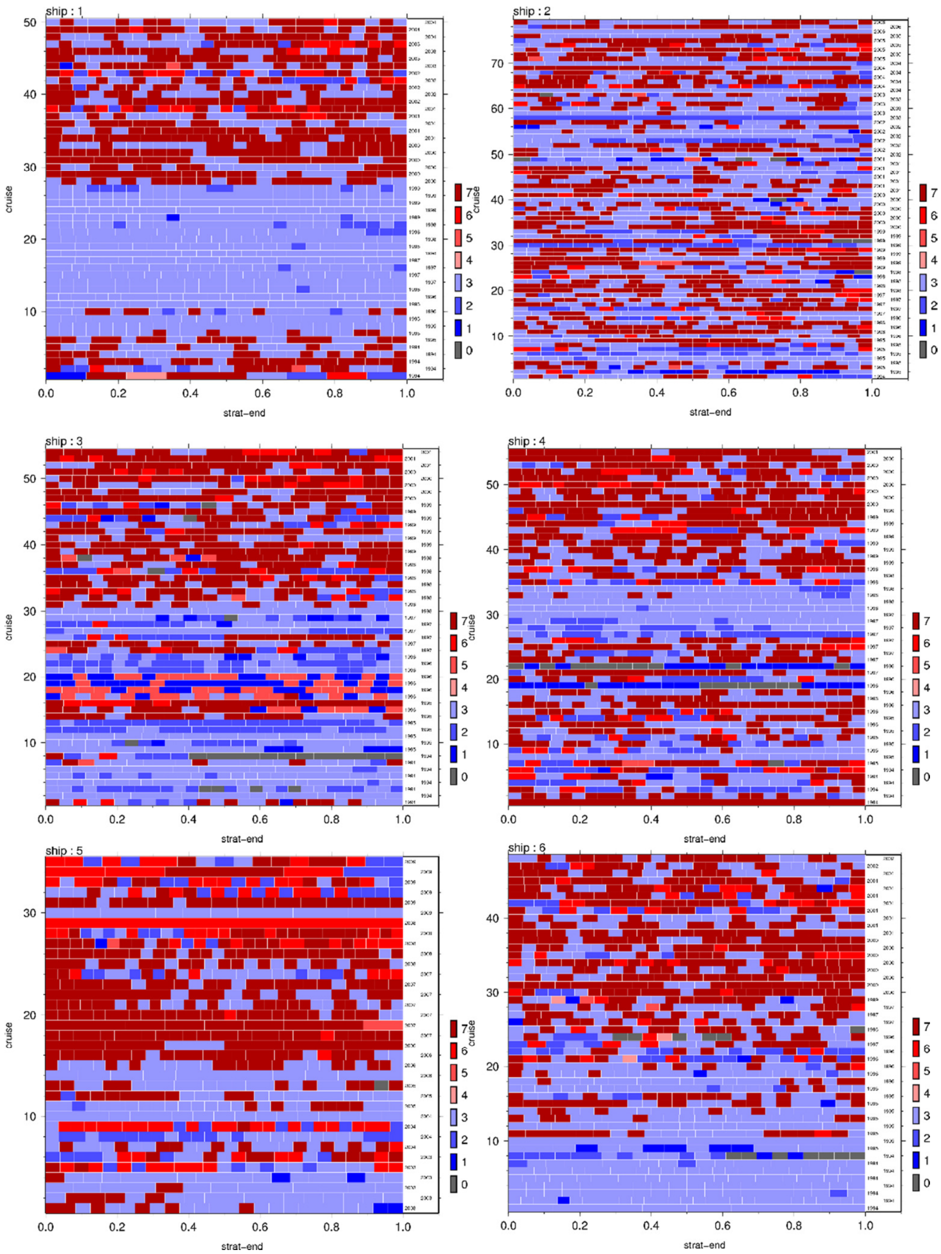


Figure A1-1. Cumulative number of the species' code (1: swordfish 2: blueshark 4: shortfin mako) by cruise (from onset to end) for 29 vessels which are filtered by filtering methods (I). Y axis indicates the time periods from old to recent years in the ascending order from the bottom. Higher concentration of red and blue color denotes higher and lower positive catch of shortfin mako, respectively. Ship No. 6, 12, 13, 14, 15, 22, 25, 26, 28 and 29 were removed by the visual observation.

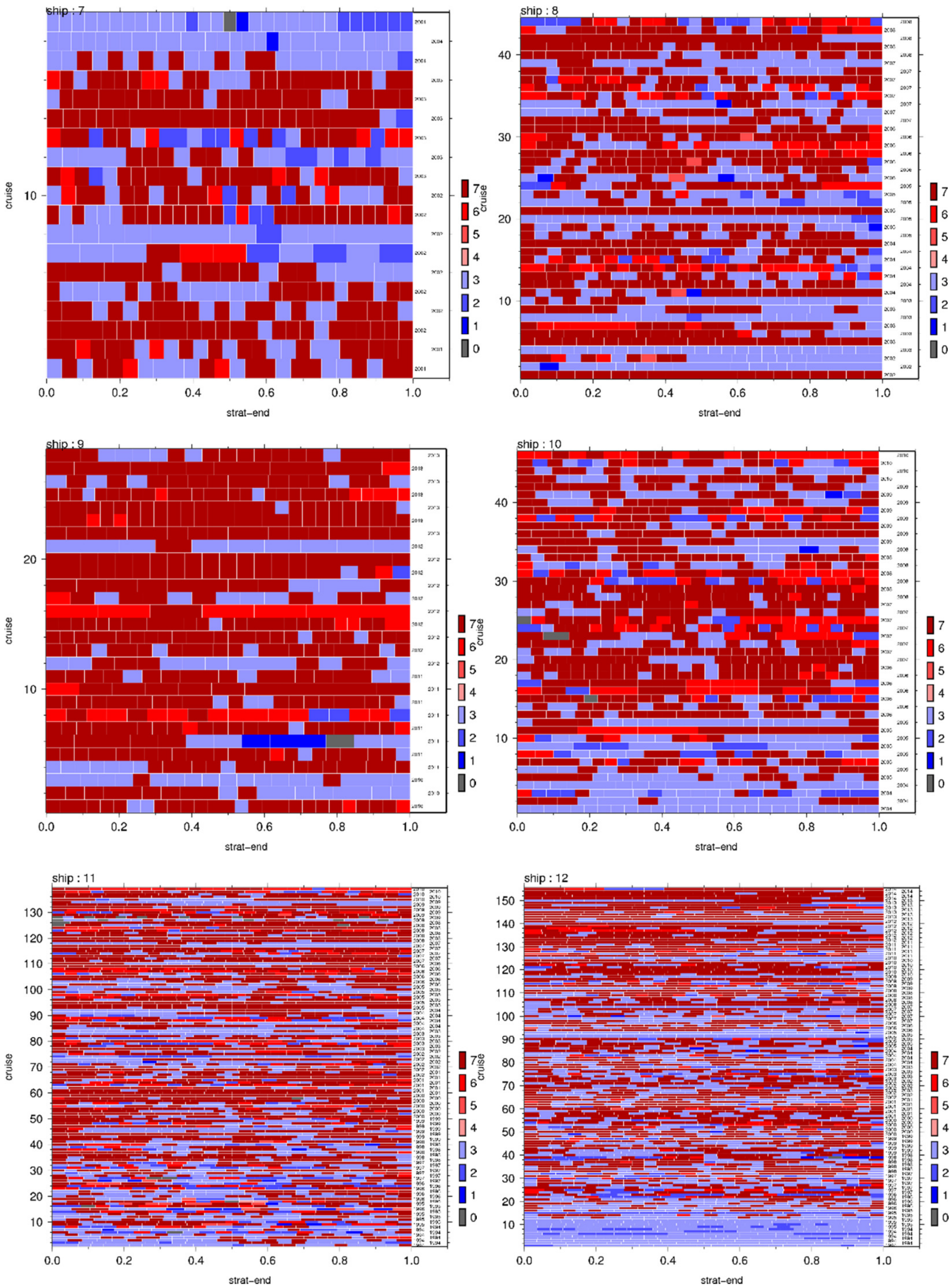
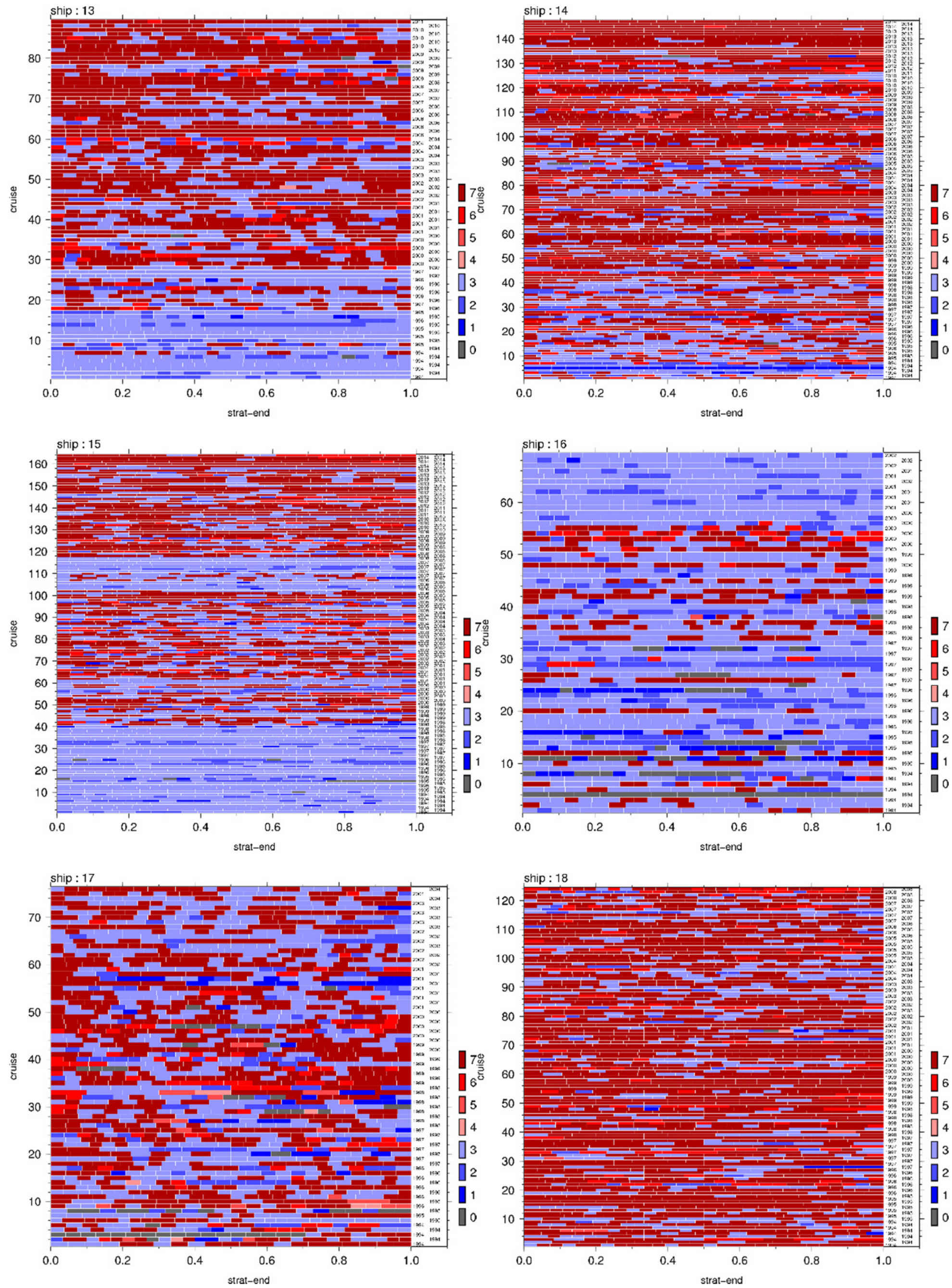


Figure A1-2. Continue.



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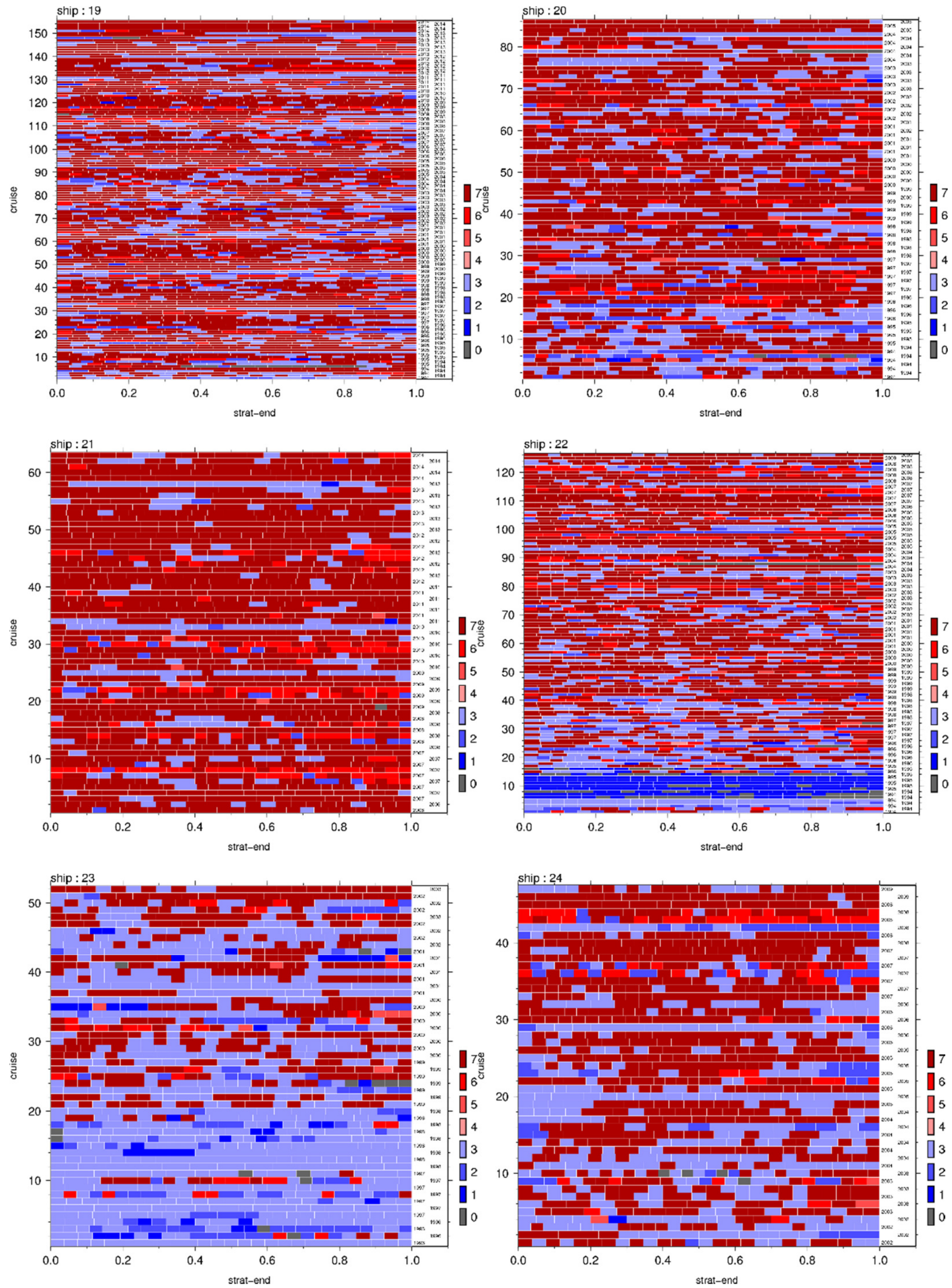

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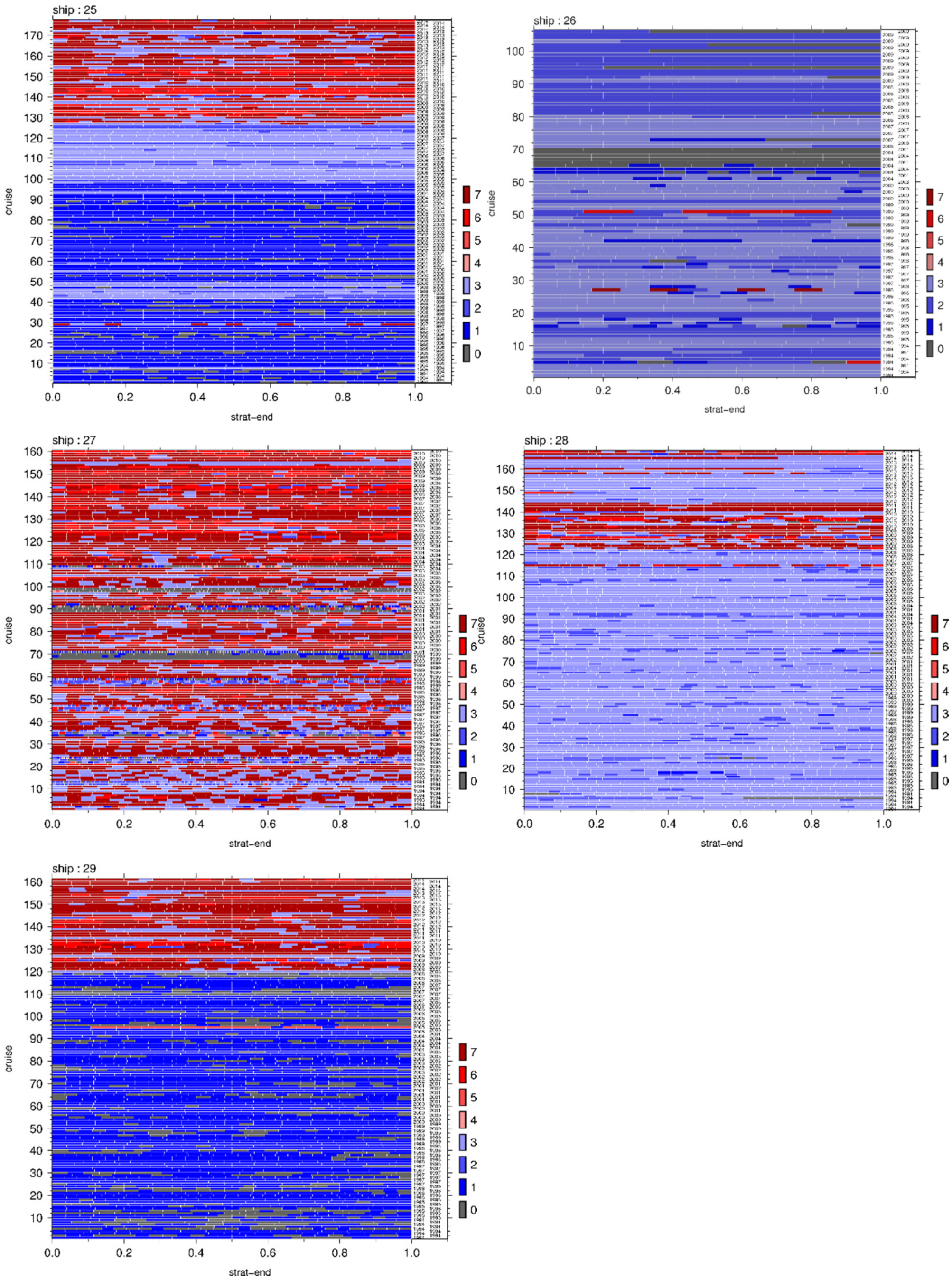

Figure A1-5. Continue.

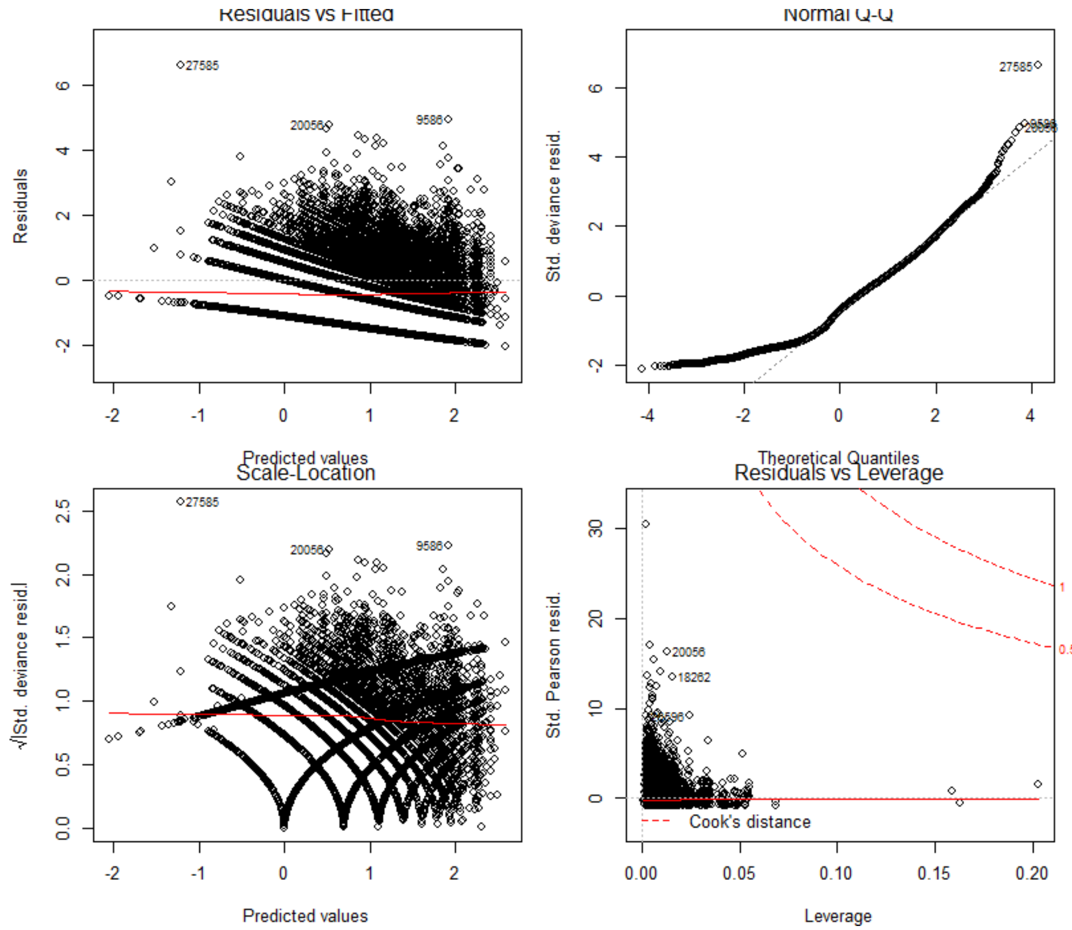

Figure A2. Diagnostics of the fittings for negative binomial model with the filtered datasets.

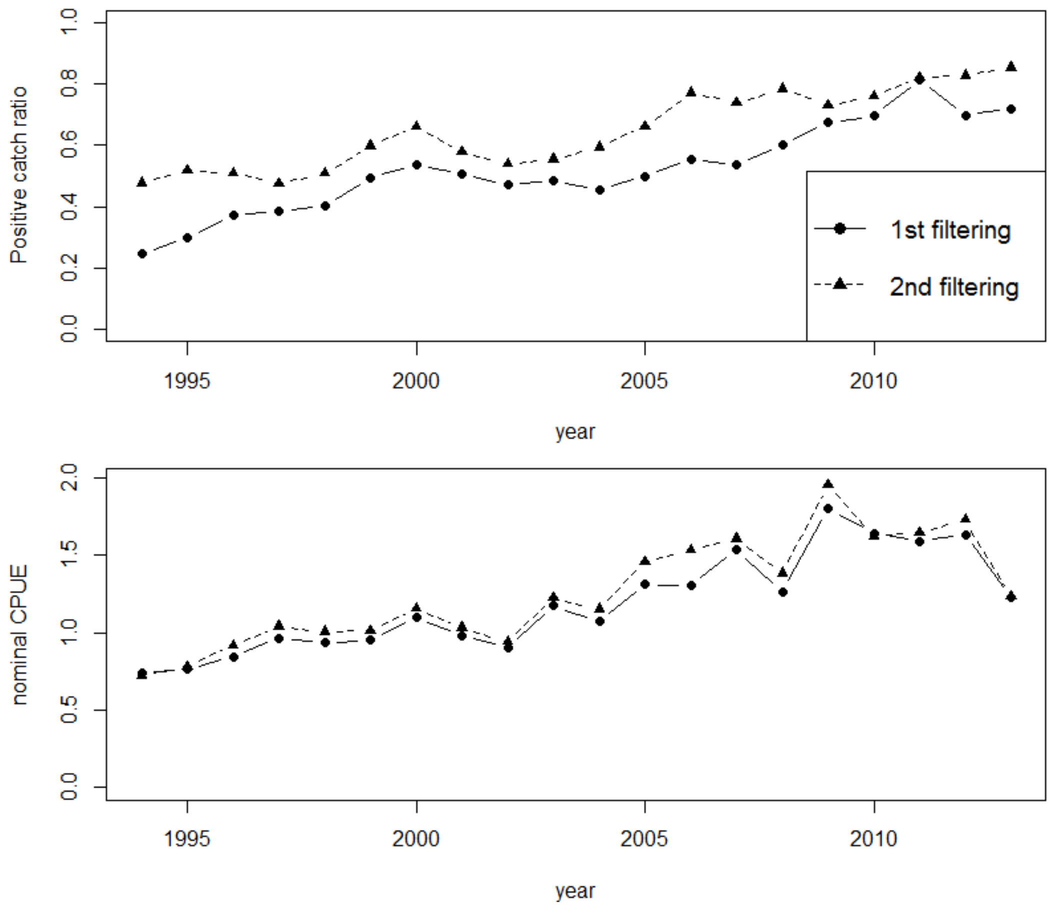

Figure A3. Yearly changes of the positive catch ratio (upper) and nominal CPUE of positive catch (lower) for the selected data by data filtering I and II.