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STANDARDIZED CPUE OF SHORTFIN MAKO (*ISURUS OXYRINCHUS*) CAUGHT BY THE JAPANESE TUNA LONGLINE FISHERY IN THE ATLANTIC OCEAN

Yasuko Semba, Kotaro Yokawa and Yuko Hiraoka

SUMMARY

*Standardized CPUE for shortfin mako (*Isurus oxyrinchus*) caught by the Japanese tuna longline fishery in the Atlantic Ocean was estimated using the logbook data from 1994 and 2010. We revised the method to extract the accurate record of the shortfin mako catch from the logbook data, based on the information of data collected in the observer program. For the North Atlantic, the standardized CPUE ranged from 0.07 to 0.1 between 1994 and 2005, and then showed a continuous increasing trend. For the South Atlantic, the standardized CPUE was stable around 0.06 from 1994 and 2006, and then indicated the continuous increasing trend as observed in the North Atlantic.*

RÉSUMÉ

*La CPUE standardisée du requin-taupe bleu (*Isurus oxyrinchus*) capturé dans le cadre de la pêcherie palangrière japonaise ciblant les thonidés dans l'océan Atlantique a été estimée au moyen des données des carnets de pêche couvrant la période 1994-2010. Nous avons révisé la méthode afin d'obtenir le registre précis des captures de requin-taupe bleu à partir des données des carnets de pêche, sur la base des informations des données recueillies dans le cadre du programme d'observateurs. En ce qui concerne l'Atlantique Nord, la CPUE standardisée oscillait entre 0,07 et 0,1 entre 1994 et 2005, et présentait ensuite une tendance à la hausse continue. Dans le cas de l'Atlantique Sud, la CPUE standardisée est restée à un niveau stable (approximativement 0,06) entre 1994 et 2006, présentant par la suite une tendance à la hausse continue, à l'instar de l'Atlantique Nord.*

RESUMEN

*Se estimó la CPUE estandarizada para el marrajo dientuso (*Isurus oxyrinchus*) capturado por la pesquería atunera de palangre japonés en el océano Atlántico utilizando los datos de cuadernos de pesca entre 1994 y 2010. Revisamos el método para extraer registros precisos de captura de marrajo dientuso de los datos de los cuadernos de pesca basándose en la información de los datos recopilados en el marco del programa de observadores. Para el Atlántico norte, la CPUE estandarizada oscilaba entre 0,07 y 0,1 entre 1994 y 2005, y posteriormente mostraba una tendencia ascendente continua. Para el Atlántico sur, la CPUE estandarizada era estable alrededor de 0,06 entre 1994 y 2006, y posteriormente mostraba una tendencia ascendente continua tal y como se observó en el Atlántico norte.*

KEYWORDS

Shortfin mako, Japanese longline fishery, standardized CPUE

1. Introduction

Standardized CPUE for shortfin mako which was caught by Japanese tuna longline fishery in the Atlantic Ocean has been reported since 2004 for the stock assessment of this shark (Senba 2005, Matsunaga 2007, 2009). Species-specific catch data for shortfin mako has been collected since 1994 in Japanese tuna longline fishery. For the period in which species was aggregated, the species-specific catch was estimated using "filtering method" devised by Nakano and Honma (1996). This method (hereafter indicated as "previous/traditional filtering method") focuses on the ratio of number of operation with any shark catch (total sharks) to the number of operation in a cruise. This ratio is called as "reporting rate" and corresponds to the occurrence ratio of any shark catch in each cruise. Nakano and Clarke (2006) verified this method and suggested that the reporting rate more than 80% is appropriate for blue shark.

Matsunaga (2009) applied this ratio (more than 80%) to extract the catch data of shortfin mako from the species-specific logbook data based on the assumption that the data from the vessel which records catch of blue shark accurately would also report that of shortfin mako accurately. However, if some vessel only records the catch of shortfin mako and the occurrence rate of shortfin mako is lower than 80%, this method does not fully contain the catch of shortfin mako.

Recent detailed investigation on the shark reporting rate for Japanese tuna longline fishery in the Atlantic indicates that the traditional filtering method based on the reporting rate of "(total) sharks" might be affected by the temporal change of species composition and the landing pattern of other species, especially by that of the most dominant species (i.e., blue shark). For example, the motivation of landing for the dominant species (e.g. the development of infrastructure and change of price for blue shark meat) will impact the reporting rate for all sharks to large extent and consequently, have influence on the extraction of other species catch. As shortfin mako has been treated as relatively high-value shark and utilized well in Japan, the application of reporting rate of shortfin mako would be better to extract the appropriate data for catch of shortfin mako from the species-specific data. In this context, previous filtering method for shortfin mako was revisited in this document. Additionally, we standardized CPUE of shortfin mako in the North and South Atlantic, based on the filtered logbook data.

2. Materials and Methods

Throughout the analysis, the logbook data of Japanese tuna longline fishery from 1994 and 2010 was used. As the reference data for the reporting rate of shortfin mako (indicated as "SFMRR" hereafter), observer data from 1997 to 2010 was used. In the Atlantic, Japanese tuna longline fishery targets different tuna species depending on the area; targeting Atlantic bluefin tuna in the mid-high latitude of the North Atlantic, targeting tropical tuna in the low latitude of the North and South Atlantic, and targeting southern bluefin tuna in the high latitude of the South Atlantic. The gear depth can be discriminated by the number of hooks per a basket. The distribution of effort, aggregated into 5 by 5 degrees, of Japanese tuna longline fishery and that of observer data in the Atlantic was shown in **Figure 1** and **Figure 2**, respectively.

2.1 Data and filtering

As the 1st step of the filtering, SFMRR was calculated for each cruise in the observer data from 1997 to 2010. The summary of information on the data used is shown in Table1. The definition of SFMRR is, the ratio of the number of operations with catch of shortfin mako to the total number of operation of a cruise. The frequent distribution of SFMRR indicates that most SFMRR was below 40% with the mode at the 0% and the observations of reporting rate over 60% appeared sporadically (**Figure 3**).

As the 2nd step, SFMRR was calculated similarly for the each cruise in the logbook data from 1994 and 2010, separately for the North and South Atlantic. The frequent distributions of SFMRR in the North and South Atlantic were shown in Figure 4.These patterns of distribution were similar to that of the observer data. The data with SFMRR >=40 % occupied 7.06% for the North and 6.89% for the South for the number of the cruise, 10.41% for the North and 4.02% for the South for the number of the operation.

As the 3rd step, because SFMRR was continuously distributed between 0% and 40% both in the observer and logbook data (both in North and South), the logbook data of SFMRR < 40% was considered to be correct and the data with SFMRR >=40 % was checked, focusing on the catch number of shortfin mako per an operation or sequentiality of positive catch in relation to the location or sea surface temperature at catch by 10% interval of SFMRR from 40 to 100 % SFMRR range.

Two kinds of possible error were detected; which are, 1) no catch from underreporting and 2) too much catch from misreporting including contamination with other species (e.g. longfin mako in the operation in the tropical area). For 1), logbook data from cruise in which no shark was caught in the cruise (i.e. reporting rate for all sharks is 0) was removed based on the fact that at least one shark was caught throughout the cruise in all cruises of the observer program. For 2), detailed definition of these errors was indicated in the **Appendix**. Based on the occurrence pattern of error, each operation was ranked from 0 to 3 as follows;

Rank 0: data with no apparent error

Rank 1: data with uncertainty on SFMRR because the fishing area was not covered by observer but assumed acceptable after the comparison of catch pattern with that of adjacent area which was covered by observer

Rank 2: data with error regarding maximum catch number per operation or continuity of positive operation (i.e. very high SFMRR)

Rank 3: data with error regarding maximum catch number per operation and continuity of positive operation (e.g. misreporting, misidentification)

Data of rank 0 and rank1 would be preferable to be used as the input data.

Figure 5 indicates the ratio of each rank within each 10% interval of SFMRR over 40% for the North and South Atlantic. In the North Atlantic, the ratio of poor data (Rank2 and Rank3) was high in the data over 70% SFMRR while the data with no apparent error (Rank0) was high in the data below 70% SFMRR. Although the error data was contained in the data with SFMRR < 70%, the baseline on the ratio of acceptable data for the analysis, was set as 50% for each interval arbitrarily in this time. Based on this, the logbook data with SFMRR < 70% was used as the input data for GLM analysis of the North Atlantic population. In the South Atlantic, most of data with high SFMRR was supposed to be erroneous as in the North Atlantic, but the amount of acceptable data within lower SFMRR category was less than that in the North Atlantic. Although error data was also contained in the low SFMRR category to some extent, the logbook data < 60% was used as the input data for the South Atlantic population, following the baseline above. When applying this method to filter the data, the acceptable data contained in the high SFMRR (i.e., removed data) was ignored because the amount of acceptable data was very small.

2.2 Models

Generalized Liner Model (GLMs) was applied to the compiled logbook data from 1994 to 2010 after using modified filtering method, separately for the North and South Atlantic in order to eliminate biases arising from differences in the effort characteristics in terms of area, fishing season and gear. The detailed information on the data used for the standardization was shown in Table2. For standardization, season was categorized into 4 quarters in every 3 months from January and area was divided into 6 subareas (**Figure 6**), based on the range of this species and the distribution of effort. Regarding the effect of gear, number of branch lines per a basket (BR) was divided into 3 categories; <9, 9-14, >14. Considering the number of 0 catch, negative binomial distribution was selected as the error structure after Matsunaga (2009). The equation for standardizing CPUE was as follows;

For the North Atlantic;
E(Catch) = (Effort)* EXP(Intercept+ YR+ QT+ AR+ BR+ YR*AR+ YR*QT+ YR*BR+ AR*BR+ QT*BR)
Catch ~ NB(α , β)

For the South Atlantic;
E(Catch) = (Effort)* EXP(Intercept+ YR+ QT+ AR+ BR+ YR*QT+ YR*BR+ QT*BR +AR*BR)   Catch ~ NB(α , β)
where Catch: catch number of shortfin mako, Effort: number of hooks, YR: effect of year, QT: effect of quarter (QT1: Jan. to Mar., QT2: Apr. to Jun., QT3: Jul. to Sep., QT4: Oct. to Dec.), AR: effect of area (Area1~3 for the North, Area4~6 for the South in Figure 6), BR: effect of gear (BR1: BR<9, BR2: 9<= BR<=14, BR3: BR>14). All main effect interaction terms were treated as categorical variable and fixed effect. Variable selection for the interaction term was conducted at the significance level of 5%.

For comparison with the past result, calculation by the method of Matsunaga (2009), including filtering method and area stratification, was conducted and the estimates were shown with the result of the present analysis. The model structure of Matsunaga (2009) was as follows,
E(Catch number) = (Effort)* EXP(Intercept + YR+ QT+ AR+ BR+ YR*QT + YR*BR +QT*BR)   Catch number ~ NB(α , β)

The GLM analysis was conducted using GENMOD procedure in SAS (ver 9.2). The yearly trend of standardized CPUE was estimated from LSMEANS in this procedure.

3. Results and Discussion

In this report, new filtering method was applied to extract the catch data of shortfin mako in the logbook. This method is based on the occurrence rate of shortfin mako in the observer data, which is assumed to be the actual pattern of occurrence for this species in the fishery. As there was no observer-onboard cruise in which shark species was not caught at all (i.e., previous reporting rate is 0) in the observer data, it was suggested that removal of the logbook data with no shark catch would filter off the under-reporting data to some extent. As another cause of error data, misreporting was checked by the survey of logbook data of SFMRR >=40%. In this procedure, error data due to miswriting of other shark species caught or that due to miswriting the sum of sharks caught instead of catch of shortfin mako was detected in the data with high SFMRR value. The reason for this trend is unclear at present, but this result provides new perspective suggesting the necessity for checking the data that previously thought as accurate data. To improve the filtering data, further understanding on the reporting and the occurrence pattern of shark catch in the fishery data is imperative via continuous collection of observer data.

The updated standardized CPUEs after procedure in Matsunaga (2009) were shown in **Figure 7**. In the North Atlantic, updated CPUE after 2006 fluctuated between 0.06 and 0.1. Compared to the period between 1996 and 2000, the level of CPUE was higher after 2004. In the South Atlantic, the updated CPUE after 2006 showed continuous increasing trend. In both cases, CPUE of shortfin mako did not show continuous decreasing trend.

In addition to the filtering method, we modified the area stratification and accordingly, the model structure for standardization was changed from the past analysis. For the North Atlantic, the area north of 60 degrees North (Area1 in Matsunaga (2009)) was removed in the present analysis because this area is not overlapped with the main distribution area for shortfin mako and the positive catch data was very small in this area. As a result of removal of this area, the interaction term between year and area could be added and the calculation converged. As ANOVA table shows (**Table 3**), this interaction was significant. For the South Atlantic, the area subdivision was modified because of the same reason as the North Atlantic analysis and also of the distribution pattern of fishing effort in the South Atlantic. The model, however, did not converge after the addition of year*area interaction, which is suggested because the distribution of effort is strongly biased (**Figure 1**) and thus the model used in this analysis could not corrected it adequately.

The standardized CPUE estimated by new approach in the present analysis were shown in Figure 8. The ANOVA table and the estimated value were indicated in **Table 3** and **Table 4**, respectively. For the North Atlantic, the estimated CPUE was higher than that in Matsunaga (2009) for the period overlapped (1994-2006). This result suggests that the data extracted by new filtering method included more information of the catch than that by previous method. The increasing trend indicated in the previous estimate between 2000 and 2004 became more stable in our estimate. After 2006, CPUE continuously increased compared to the updated CPUE of Matsunaga (2009) which showed stable trend (**Figure 7**). For the South Atlantic, the estimated CPUE was lower especially in the beginning and the end of the overlapped period and smoother than that by Matsunaga (2009)'s one. Considering the life history traits of this species, less fluctuation of the CPUE, suggested in the current estimate, is reasonable. Throughout the period, CPUE was stable from 1994 to 2006 and then it increased gradually.

In conclusion, the results in the present analysis suggests that 1) the past filtering method for shortfin mako may lose the catch information for shortfin mako and contain some error data, and 2) shortfin mako population is not likely to decline both in the North and South Atlantic in recent years.

4. References

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Table 1. Summary of information on the observer data used.

	No. of cruise	No. of hook	No. of operation
1997	5	697,232	294
1998	2	322,434	133
1999	2	669,159	265
2000	4	427,447	149
2001	9	1,194,494	426
2002	8	1,509,800	503
2003	9	1,417,127	465
2004	9	1,117,536	366
2005	10	1,555,264	504
2006	7	1,091,782	378
2007	8	1,282,617	422
2008	9	1,640,025	575
2009	8	1,007,478	349
2010	8	1,049,408	356

Table 2. The detailed information on the data used for the GLM analysis for the South Atlantic, the data of gear 1 (number of hooks per a basket < 9) was removed in the analysis because of convergent problem.

North Atlantic

Number of Observations Used	159,055

year	No. of observation
1994	8,490
1995	8,200
1996	10,729
1997	9,657
1998	9,604
1999	8,251
2000	8,828
2001	8,828
2002	7,027
2003	8,141
2004	10,390
2005	12,128
2006	9,759
2007	8,035
2008	10,127
2009	10,561
2010	10,300

Area	No. of observation
1	26,666
2	33,023
3	99,366

Quarter	No. of observation
1	57,583
2	36,679
3	28,976
4	35,817

Gear	No. of observation
1	36,536
2	26,096
3	96,423

South Atlantic

Number of Observations Used	137,064

year	No. of observation
1994	13,477
1995	12,795
1996	11,754
1997	8,963
1998	7,485
1999	7,925
2000	8,467
2001	4,522
2002	4,077
2003	8,226
2004	6,009
2005	3,872
2006	6,018
2007	6,000
2008	10,106
2009	8,470
2010	8,898

Area	No. of observation
4	102,391
5	1,283
6	33,390

Quarter	No. of observation
1	34,295
2	39,249
3	23,832
4	39,688

Gear	No. of observation
1	4,372
2	57,490
3	75,202

Table 3. Analysis of variance for GLMs for the North (left) and South (right) Atlantic.

Source	DF	Chi-Square	Pr > ChiSq
year	16	533.06	<.0001
qt	3	12.83	0.005
area	2	117.78	<.0001
br	2	151	<.0001
year*area	32	910.42	<.0001
area*br	4	100.3	<.0001
year*qt	48	804.93	<.0001
year*br	32	818.38	<.0001
qt*br	6	536.17	<.0001

Source	DF	Chi-Square	Pr > ChiSq
year	16	896.47	<.0001
qt	3	91.32	<.0001
area	2	10.74	0.0047
br	1	0.76	0.3824
qt*area	6	357.22	<.0001
area*br	2	9	0.0111
year*qt	48	813.38	<.0001
year*br	16	475.8	<.0001
qt*br	3	43.11	<.0001

Table 4. Standardized CPUE and 95% confidence intervals for shortfin mako based on the logbook data of Japanese tuna longline fishery in the North (left) and the South (right) Atlantic.

	95%_lower	estimate	95%_upper
1994	0.1065	0.1179	0.1305
1995	0.0651	0.0740	0.0841
1996	0.0635	0.0708	0.0790
1997	0.1037	0.1131	0.1235
1998	0.0782	0.0853	0.0932
1999	0.0663	0.0733	0.0809
2000	0.0607	0.0670	0.0740
2001	0.0836	0.0906	0.0981
2002	0.0706	0.0779	0.0860
2003	0.0906	0.0986	0.1074
2004	0.0709	0.0765	0.0824
2005	0.0724	0.0777	0.0834
2006	0.1054	0.1135	0.1222
2007	0.1106	0.1227	0.1361
2008	0.1228	0.1349	0.1482
2009	0.1496	0.1696	0.1923
2010	0.1325	0.1594	0.1917

	95%_lower	estimate	95%_upper
1994	0.05672	0.07363	0.09559
1995	0.04208	0.05479	0.07134
1996	0.03829	0.04997	0.06522
1997	0.05553	0.07238	0.09435
1998	0.03943	0.05181	0.06809
1999	0.0332	0.0435	0.05698
2000	0.04229	0.05523	0.07212
2001	0.03967	0.05256	0.06964
2002	0.04074	0.05389	0.07128
2003	0.04335	0.05667	0.07407
2004	0.04623	0.06075	0.07984
2005	0.04663	0.06156	0.08126
2006	0.04737	0.06229	0.08191
2007	0.05988	0.0788	0.10368
2008	0.07002	0.0911	0.11852
2009	0.08135	0.10565	0.13721
2010	0.10255	0.13321	0.17303

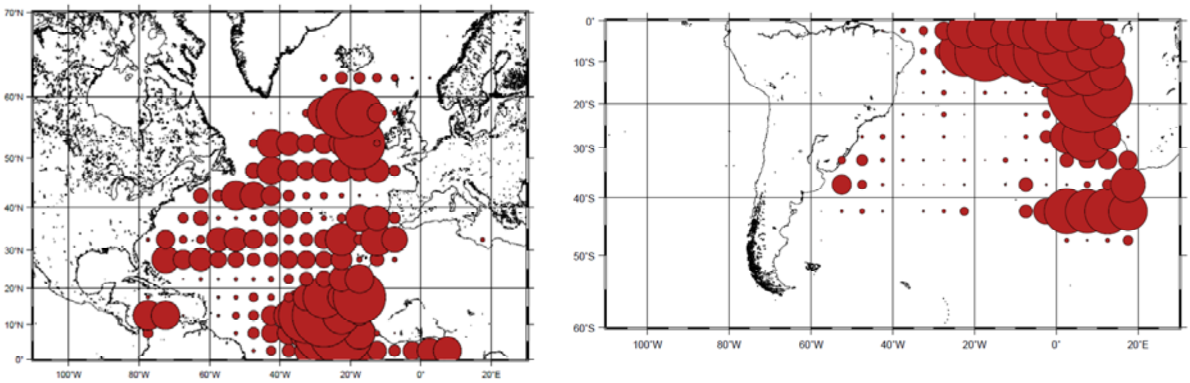

Figure 1. Distribution of effort by Japanese tuna longline fishery in the North (left) and South (right) Atlantic.

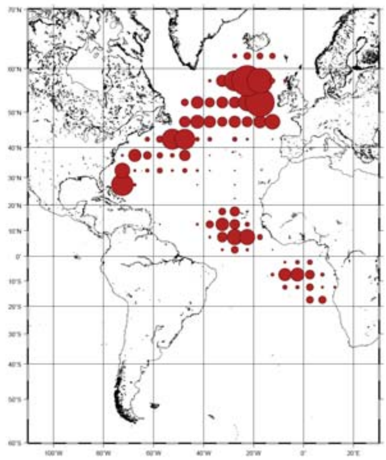

Figure 2. Distribution of effort in the observer data for Japanese tuna longline fishery in the Atlantic.

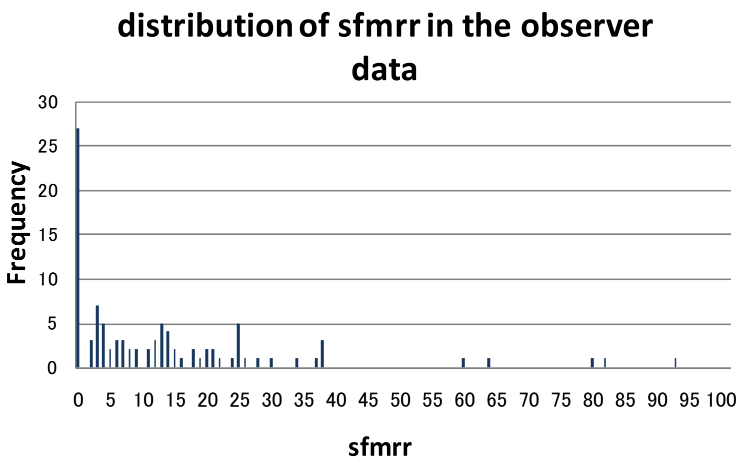

Figure 3. Frequency distribution of SFMRR in the observer data.

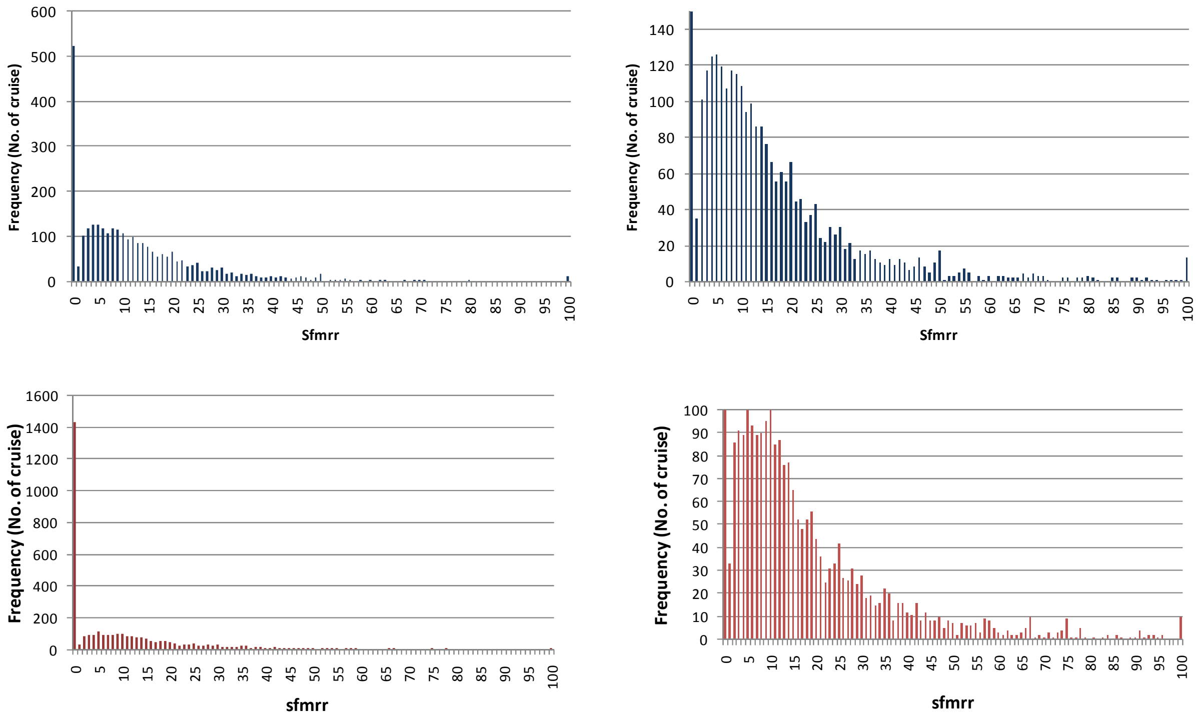

Figure 4. Frequency distribution of SFMRR in the logbook data for the North (Upper) and South (Lower) Atlantic In both Oceans, right figures show the enlarged part of the frequency distribution except for 0% SFMRR.

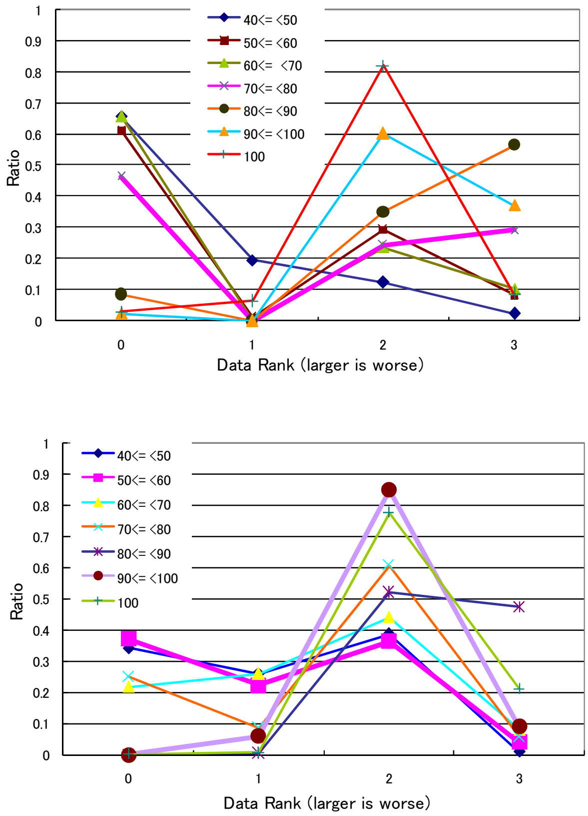

Figure 5. Ratio of occurrence of data rank in each SFMRR in 10% interval for the North Atlantic (Upper) and the South Atlantic (Lower).

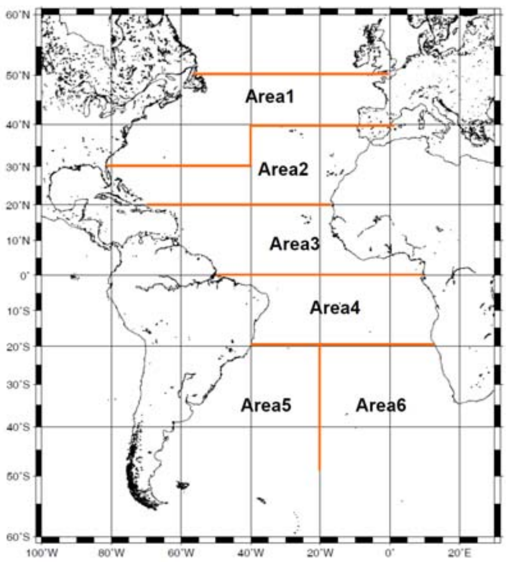

Figure 6. The area subdivision used in the GLM analysis.

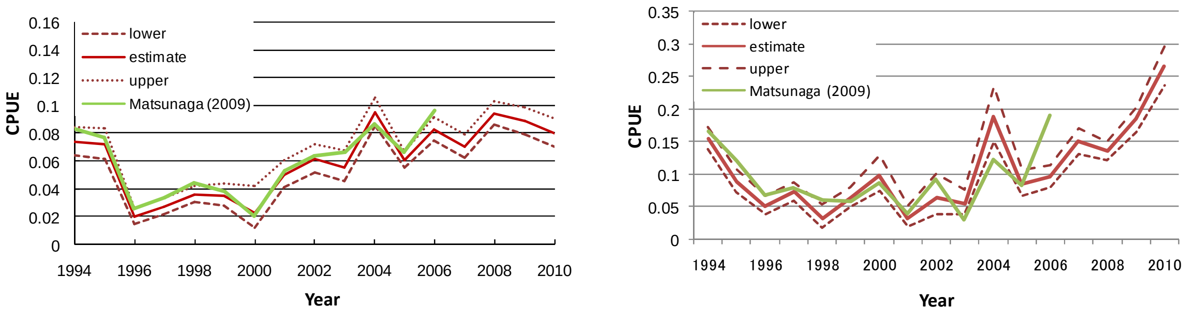

Figure 7. Updated standardized CPUE after Matsunaga (2009) for the North (left) and South (right) Atlantic. Data used was compiled by the filtering method after Matsunaga (2009).

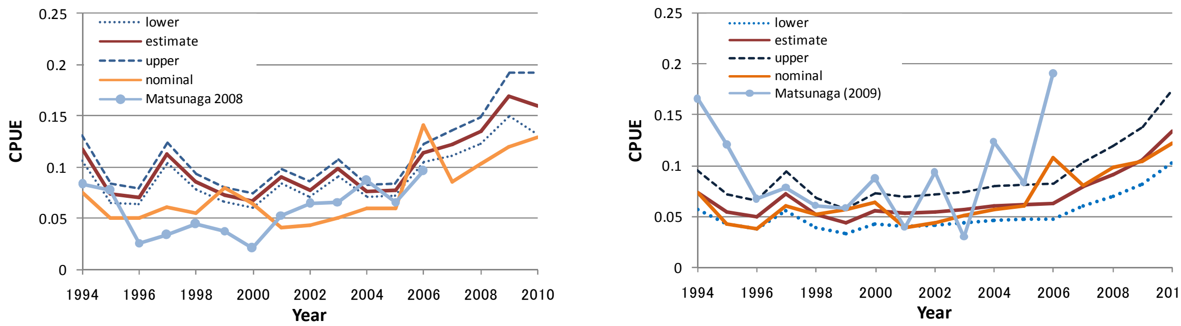

Figure 8. Standardized CPUE estimated in the present analysis for the North (left) and South (right) Atlantic. Nominal CPUE was calculated from the data filtered by new method.

Appendix

The definition of error data used in this analysis

To detect the error data, two kinds of error were assumed; 1) underreporting and 2) misreporting (too much catch) from misidentification with other species. For misidentification, species of candidates are blue shark and porbeagle in the area of high latitude and longfin mako in the area of low latitude.

From the record of observer data, the following characteristics were identified and used as the base for identification of error.

1. Maximum number of shortfin mako per operation (ca. 3000 hooks) is smaller than 10.
2. Shortfin mako was not recorded continuously in the low latitude (from equator to 20 degrees N and S)
3. Shortfin mako was not recorded frequently in the high latitude with Sea Surface Temperature (SST) cooler than 12-13℃, especially in the North Atlantic.
4. Shortfin mako is recorded most frequently in the particular SST (between 15 to 20 ℃) and as warmer or cooler, the catch number get smaller (**Figure 7**).

Based on this, SFMRR was examined by area and the following definition of error was developed.

1. The data of cruise in which SFMRR is larger than 20% and more than 10 sharks area caught continuously in the low latitude.
2. The data of cruise in which more than 10 sharks area caught continuously in the area of high latitude (cooler than 12-13℃)

In this analysis, check of error data was conducted only for the logbook data with SFMRR >=40%.

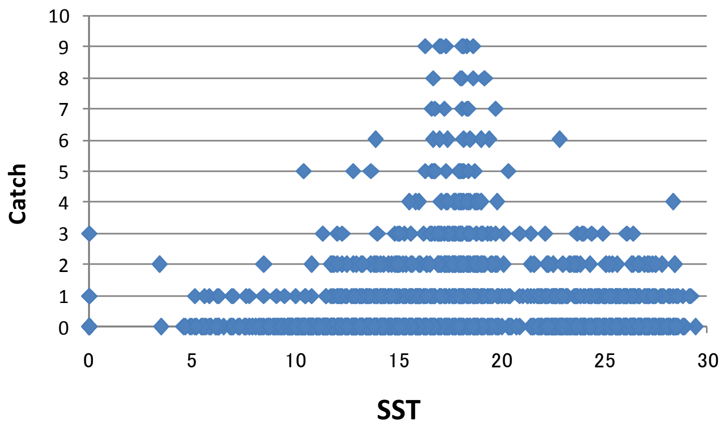

Figure 9. The relationship between the catch number of shortfin mako per operation and sea surface temperature (SST) derived from the observer data.