SCRS/2017/054 Collect. Vol. Sci. Pap. ICCAT, 74(4): 1613-1627 (2017)

REVISED STANDARDIZED CPUE OF SHORTFIN MAKO (*ISURUS OXYRINCHUS*) CAUGHT BY THE JAPANESE TUNA LONGLINE FISHERY IN THE NORTH ATLANTIC OCEAN BETWEEN 1994 AND 2015

Yasuko Semba[1][2], Mikihiko Kai[1] and Kotaro Yokawa[1]

SUMMARY

*Previous estimates of standardized CPUE for shortfin mako (*Isurus oxyrinchus*) caught by the Japanese tuna longline fishery in the Atlantic Ocean were revised with consideration for the temporal changes in the operational pattern for the Japanese fleet in the North Atlantic between 1994 and 2015. Investigation of spatiotemporal distribution of fishing effort suggested that displacement of fishing effort for Atlantic bluefin tuna (*Thunnus thynnus*) especially in the area north of 20° N caused an unrealistic decline of CPUE for the North Atlantic shortfin mako in the past five years in the previous analysis. Based on the investigation of number of set and nominal CPUE of shortfin mako, area stratification was revised and explanatory variables included in GLM analysis were modified. Following the data filtering described in Semba* et al. *(2012), CPUE of North Atlantic shortfin mako was standardized using zero inflated negative binomial model. The revised abundance index showed a declining trend in the earliest few years and a stable trend around 0.1 (fish/1000 hooks) between 1995 and 2005, followed by a continuous increasing and declining trend between 2005 and 2013. Although uncertainty has been left in the estimates of several years, the current analysis improved the uncertainty indicated since the late 2000s in the past analysis and suggested that annual trend of the abundance index would not show a continuous increasing/decreasing trend between 1994 and 2015.*

RÉSUMÉ

*De précédentes estimations de la CPUE standardisée du requin-taupe bleu (*Isurus oxyrinchus*) capturé par la pêcherie palangrière japonaise ciblant les thonidés dans l'océan Atlantique ont été révisées en tenant compte des changements temporels dans le schéma opérationnel de la flottille japonaise opérant dans l'Atlantique Nord entre 1994 et 2015. L'enquête sur la distribution spatio-temporelle de l'effort de pêche a suggéré que le déplacement de l'effort de pêche dirigé sur le thon rouge (*Thunnus thynnus*), dans la zone au Nord de 20°N, a provoqué une chute irréaliste de la CPUE du requin-taupe bleu de l'Atlantique Nord au cours des cinq dernières années dans l'analyse précédente. D'après l'enquête sur le nombre d'opérations et de CPUE nominale du requin-taupe bleu, la stratification de la zone a été révisée et les variables explicatives incluses dans l'analyse GLM ont été modifiées. L'indice d'abondance révisé a montré une tendance à la baisse dans les premières années et une tendance stable entre 1995 et 2005, suivie d'une tendance continuellement à la hausse et à la baisse entre 2005 et 2013. En dépit de l'incertitude, la présente analyse a réduit l'incertitude depuis la fin des années 2000 dans l'analyse antérieure et suggère que la tendance annuelle de l'indice d'abondance ne montrerait pas une tendance à la hausse/baisse continue entre 1994 et 2015.*

RESUMEN

*Se revisan estimaciones previas de la CPUE estandarizada para el marrajo dientuso (*Isurus oxyrinchus*) capturado por la pesquería atunera de palangre japonés en el océano Atlántico teniendo en consideración los cambios temporales en el patrón operativo de la flota japonesa en el Atlántico norte entre 1994 y 2015. La investigación sobre la distribución espaciotemporal del esfuerzo pesquero sugería que el desplazamiento del esfuerzo pesquero dirigido al atún rojo del Atlántico (*Thunnus thynnus*) en la zona al norte de 20ºN, causó un descenso poco realista en la CPUE del marrajo dientuso del Atlántico norte en los cinco últimos años en el análisis anterior. Basándose en la investigación del número de lances y de la CPUE nominal del marrajo dientuso, se revisó la estratificación del área y se modificaron las variables explicativas incluidas en el análisis de GLM. El índice de abundancia revisada mostraba una tendencia descendente en los primeros años y una tendencia estable entre 1995 y 2005, seguida de una tendencia creciente y decreciente continua entre 2005 y 2013. Aunque sigue existiendo incertidumbre, el análisis actual ha mejorado la incertidumbre desde finales de los 2000 en el pasado análisis y sugiere que la tendencia anual del índice de abundancia no presentaría una tendencia creciente/decreciente continua entre 1994 y 2015.*

---

[1] NRIFSF. 5-7-1, Orido, Shimizu, Shizuoka, 424-8633. Japan.

[2] senbamak@affrc.go.jp

KEYWORDS

Shortfin mako, Japanese longline fishery, standardized CPUE

1. Introduction

Update of standardized CPUE (catch number per 1000 hooks) for shortfin mako which was caught by Japanese tuna longline fishery in the Atlantic Ocean was conducted, based on the logbook data between 1994 and 2014 (Semba *et al*. 2016). In the update, the same factors (i.e., categories) such as year, area, quarter, and gear effect in Semba *et al*. (2012) were used for the standardization of CPUE, while zero-inflated negative binomial model (ZINB) was applied for the generalized linear model (GLM) analysis, instead of negative binomial (NB) used in Semba *et al*. (2012). Regarding the area stratification, Semba *et al*. (2012) modified that used in Matsunaga (2008, 2009) by removing the area north of 50˚N, which was suggested to be beyond the main distribution area of shortfin mako.

Estimated trend of abundance index was stable around 0.1 between 1995 and 2008, followed by increase between 2008 and 2009 and rapid decrease from 0.24 to 0.05 after that. This rapid increase and one-fifth decline in few years is unrealistic from the perspective of the life history traits of this species and the recent decline of fishing effort of Japanese longline fishery in the North Atlantic. Semba *et al*. (2016) suggested that the effect by the change of operation pattern by fishing vessel targeting for Atlantic bluefin tuna (ABT) might not be taken into consideration in the process of standardization. Thus, the review of spatiotemporal distribution pattern of Japanese tuna longline fishery in the North Atlantic and the revision of CPUE standardization of this population were left to be done before the stock assessment of this population.

In this document, the spatio-temporal trend of fishing effort and pattern of operation by Japanese fleet in the North Atlantic was investigated. Based on this, the area stratification was modified and revision of CPUE standardization was conducted. In this process, the filtering of logbook data was conducted, following the threshold suggested in Semba *et al*. (2016).

2. Materials and Methods

Throughout the analysis, the logbook data of Japanese tuna longline fishery collected in the North Atlantic from 1994 and 2015 was used. Regarding the filtering of logbook data, the ratio of number of set with the aggregated shark catch (total sharks) to the total number of set in a cruise was calculated and described as “reporting rate (RR)” hereafter. RR corresponds to the occurrence rate of the set with any shark catch in each cruise. In addition, we calculated reporting rate based on shortfin mako catch (i.e., the ratio of the number of sets with catch of shortfin mako to the total number of set of a cruise) for each cruise (hereafter, indicated as SFMRR), instead of that using species-aggregated shark catch (i.e., RR).

2.1 Temporal change of fishing effort and operational pattern

In order to check the temporal changes in the distributional pattern of Japanese fleet in the North Atlantic, fishing effort was aggregated by 5 and 5 degree and mapped for 1994-1997, 1998-2001, 2002-2005, 2006-2009, 2010-2013, and 2014-2015. In order to understand the changes in operational pattern on fine scale, North Atlantic was divided into 8 subareas (west of 40°W:1) 40-50°N,2) 30-40°N,3) 20-30°N,4) 0-20°N, east of 40°W:5) 40-50°N,6) 30-40°N,7) 20-30°N,8) 0-20°N).

Then the annual number of set, hooks per basket (HPB), and annual trend of nominal CPUE of this population were calculated in each subarea. A series of calculation was conducted based on the logbook data before filtering, except for the logbook data with extremely small and large HPB.

2.2 CPUE analysis

In advance of CPUE standardization, filtering of logbook data was conducted by the following step (Semba *et al*. 2012, 2016);
1) logbook data in the area north of 50˚N was removed.
2) logbook data with RR of 0% was removed.
3) logbook data with SFMRR < 70% was filtered.

4) logbook data with no effort and HPB < 3 and >31 was removed

The data after these filtering was used for the analysis.

Regarding 1), the logbook data south of 50˚ N was used after Semba *et al*. (2012) because the area north of 50˚ N is beyond the main distribution area for shortfin mako and the positive catch data was very small in this area. Regarding 2), the cruise without any shark catch (i.e., species-aggregated shark reporting rate is 0) was removed because there was no cruise in which any shark species was not caught at all in the observer data. Thus, the logbook data with RR of 0 is suggested that fishermen release all sharks and such data is suggested not to be informative in the standardization. The detailed information on the filtered logbook data used for the standardization was shown in Table1 and Appendix 1.

For standardization, season was categorized into 4 quarters in every 3 months from January and area subdivision was revised into 3 areas, based on the spatio-temporal distribution of effort and nominal CPUE of shortfin mako in each subareas (discussed later). Regarding the effect of gear, HPB can be used as the proxy of the depth of the longline gear.

After Semba *et al*. (2016), three different GLMs, NB, zero-inflated Poisson model (ZIP), and ZINB, were applied to the filtered data and these models were evaluated based on AIC. For the selected model with the lowest AIC, annual trend of CPUE was calculated based on both standardized and normalized CPUE with nominal CPUE. The equations for standardizing CPUE were as follows;

NB:

$E(Catch) = Effort^{*} \exp(Intercept + YR + AR + QT + BR + AR^{*}QT) \qquad Catch \sim NB(k, p) \qquad (1)$
,where Catch: catch number of shortfin mako, Effort: number of hooks / 1000, YR: year effect, QT: quarter effect (QT1: Jan. to Mar., QT2: Apr. to Jun., QT3: Jul. to Sep., QT4: Oct. to Dec.), AR: area effect (Area1~3), BR: gear effect (BR1: HPB<11, BR2: 10<= HPB<=15, BR3: HPB>15), k and p are parameters of negative binomial distribution. Link function is logarithm and Effort was used as offset term. All main effect were treated as categorical variable and fixed effect.

ZIP and ZINB:

Count model: same predictor for those in NB $\quad Catch \sim P_0(\lambda) \quad$ or $Catch \sim NB(k, p) \qquad (2)$
, where λ is mean value of poison distribution.
Zero-inflated model: same predictor for those in count model $\quad$ False zero probability~ $B_i(n, p) \qquad (3)$
, where n is the number of samples and p is probability. Link function in the count model and zero-inflated model is log and logit, respectively. Effort (number of hooks / 1000) was used as offset term in the count model.

Annual changes in abundance index (standardized CPUE) was estimated by calculating every combination of four factors and taking the average for each year. For the selected model, the 95% confidence interval for the estimates of annual CPUE was estimated by bootstrap with one hundred replicates. The GLM analysis was conducted using R 3.2.2 (R Core Team 2015).

3. Results and Discussion

Temporal change of fishing effort and operational pattern

As indicated in Figure 1, the number of hooks rapidly decreased in the area north of 20°N (subarctic and temperate area) and majority of the observation was obtained from area 3 (tropical area) in recent 5 years.

Temporal changes in number of set was also indicated, and similar trend was observed in recent years, especially in the area north of 20°N (Figure 2). In subareas 2-5, fishing effort was very scarce between 2010 and 2015. As described in the Kimoto *et al*. (2015), it is suggested that these changes are related to the changes of operational pattern by longline fishery targeting for ABT. In the eastern area, the decline of TAC as well as increase of CPUE for ABT probably decreased the number of set in this area. In the western area, the northern shift of effort targeting for ABT (from area between 35 and 40˚N to north of 40˚N) and intrinsic decrease of fishing vessel operating in the Atlantic probably decreased the number of set.

Distribution of HPB in each subarea suggested that ABT was the main target in subareas1,2, and 4 and both ABT and tropical tuna were targeted in subareas 3,5,6 and tropical tuna was the main target in subareas 7 and 8 (**Figure 3**).

Nominal CPUEs in each subarea indicated that shortfin mako's CPUE was very low in subareas 1,2, and 4 with spike observed in several years and relatively high CPUE and much larger fluctuation was observed in subareas 3,5, and 6 (Figure 4). In subareas 7 and 8 (tropical area), CPUE was low as in northern areas but more stable than northern areas (Figure 4). Size frequency from Japanese observer data by each subarea were shown in Appendix 2.

GLM modelling

Taken into the pattern of fishing operation and nominal CPUE as well as the number of observation in each subarea, the area stratification was modified as indicated in Figure 5.

In the current analysis, ZINB was selected with the lowest AIC compared to NB and ZIP (Table2). Regarding the explanatory variables, main effects of year, area, quarter, and gear and only interaction term between area and quarter was included in the current model. All of these main effects and interaction term was statistically significant and effect of area was suggested to be large in the preliminary analysis. However, skewed distribution of observation of each covariate (Appendix), especially by year, did not allow us to include meaningful interaction term between year and other covariates by preventing convergence of calculation and by causing large uncertainty for the estimates. Regarding the interaction between year and area, paucity of observation in area 1 and area2, especially after 2009, would prevent the standardization and provide less reliable estimates.

Despite the revision of area stratification in current analysis, the temporal change of effort distribution and resulting bias of observation on spatial scale were so large that it would not be realistic to obtain the dataset with balanced observation in each area with further work. The observation in the tropical area has been relatively stable compared to other areas (Figure 2), investigation for the availability of logbook data focusing on this region might be useful to utilize Japanese longline data.

Trend of abundance

The revised standardized CPUEs for North Atlantic shortfin mako were shown with confidence interval for each year in Figure 6. Estimates of annual standardized CPUE with CV were indicated in Table 3. After initial decline between 1994 and 1995, standardized CPUE in the North Atlantic was stable around 0.1 until 2005 and then showed a sharp increasing trend until 2008, followed by decreasing trend until 2013. Although the general trend was similar to that estimated in the previous document, unrealistic spike or rapid increasing (2008) /decreasing (2009-2013) trend and broad confidence interval observed around early 2010s in the previous results were improved in the current estimate. This is probably due to the effect of interaction between year and area which was removed in the current analysis.

Despite some improvement, two-fold increase between 2005 and 2008 and decrease by half between 2010 and 2013 was observed with relatively wide confidence interval, which was suggested to be caused by the data in subarea 1 (Figure 4). It is uncertain that this increase/decrease reflects population dynamics at present, examination of fishing behavior by each vessel in the specified fishing ground (e.g., north area where ABT is targeted for) and consideration of inclusion of vessel effect in the GLM would improve the abundance index of this population. Although uncertainty has been still left, it was suggested that abundance trend of northern population does not show any continuous increasing/decreasing trend throughout the period analyzed.

The comparison of standardized CPUE with nominal CPUE and other estimates after normalization were shown in Figure 7. The normalized CPUE of ZINB was similar to those of other CPUEs until 1998. After that, it shifted lower level than average between 2000 and 2005, but became much larger level than average between 2008 and 2010, compared to trend of nominal CPUE. The comparison between fitted value and predicted value was shown in Figure 8.

In conclusion, the present analysis 1) improved the abundance index of North Atlantic shortfin mako taking into consideration for the temporal changes in the operational pattern by Japanese tuna longline fishery in this area and 2) indicated that annual trends in abundance index would not show any increasing/decreasing trend between 1994 and 2015 with some uncertainty left between 2005 and 2013.

References

Kimoto, A., Takeuchi, Y., and Itoh, T. 2015, Updated standardized bluefin CPUE from the Japanese longline fishery in the Atlantic to 2015 fishing year. . Collect. Vol. Sci. Pap. ICCAT, 72(6): 1636-1655.

Matsunaga, H. 2008, Standardized CPUE for shortfin mako caught by the Japanese tuna longline fishery in the Atlantic Ocean, 1994-2005. Collect. Vol. Sci. Pap. ICCAT, 62(5):1581-1586.

Matsunaga, H. 2009, Standardized CPUE for blue shark and shortfin mako caught by the Japanese tuna longline fishery in the Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 64(5):1677-1682.

R Core Team 2015, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Semba, Y., Yokawa, K., and Hiraoka Y. 2012. Standardized CPUE of shortfin mako (*Isurus oxyrinchus*) caught by the Japanese tuna longline fishery in the Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 69(4): 1615-1624.

Semba, Y., and Yokawa, K. 2016. Update of standardized PUCE of shortfin mako (*Isurus oxyrinchus*) caught by the Japanese tuna longline fishery in the Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 73(2): 868-882.

Table 1. The detailed information on the data used for the GLM analysis.

North Atlantic	
No. of observation used	188,950

Year	No. of observation
1994	8,250
1995	8,225
1996	10,696
1997	9,533
1998	9,621
1999	8,241
2000	8,765
2001	8,827
2002	6,968
2003	8,115
2004	10,368
2005	12,128
2006	9,688
2007	7,635
2008	9,139
2009	9,950
2010	10,016
2011	8,012
2012	7,745
2013	6,095
2014	5,916
2015	5,017

Area	No. of observation
1	36,584
2	25,895
3	126,471

Quarter	No. of observation
1	72,175
2	42,774
3	32,998
4	41,003

Gear	No. of observation
1	51,566
2	26,427
3	110,957

Table 2. AIC values for three model analysis of CPUE for shortfin mako in the North Atlantic.

	Negative binomial GLM	zero-inflated Poisson GLM	zero-inflated NB GLM
North Atlantic	198909.7	215748.1	197117.3

Table 3. Standardized CPUE and CV for shortfin mako based on the logbook data of Japanese tuna longline fishery in the North Atlantic.

	North Atlantic	
	Estimates of standardized CPUE	C.V.
1994	0.1790	0.0549
1995	0.1084	0.0492
1996	0.1116	0.0380
1997	0.1125	0.0571
1998	0.0920	0.0520
1999	0.0793	0.0610
2000	0.0808	0.0402
2001	0.1157	0.0532
2002	0.1179	0.0595
2003	0.1056	0.0575
2004	0.0988	0.0463
2005	0.0959	0.0368
2006	0.1334	0.0593
2007	0.1361	0.0605
2008	0.2097	0.0700
2009	0.2012	0.0595
2010	0.2171	0.0536
2011	0.1409	0.0610
2012	0.1143	0.0630
2013	0.0839	0.0733
2014	0.1670	0.0633
2015	0.0915	0.0672

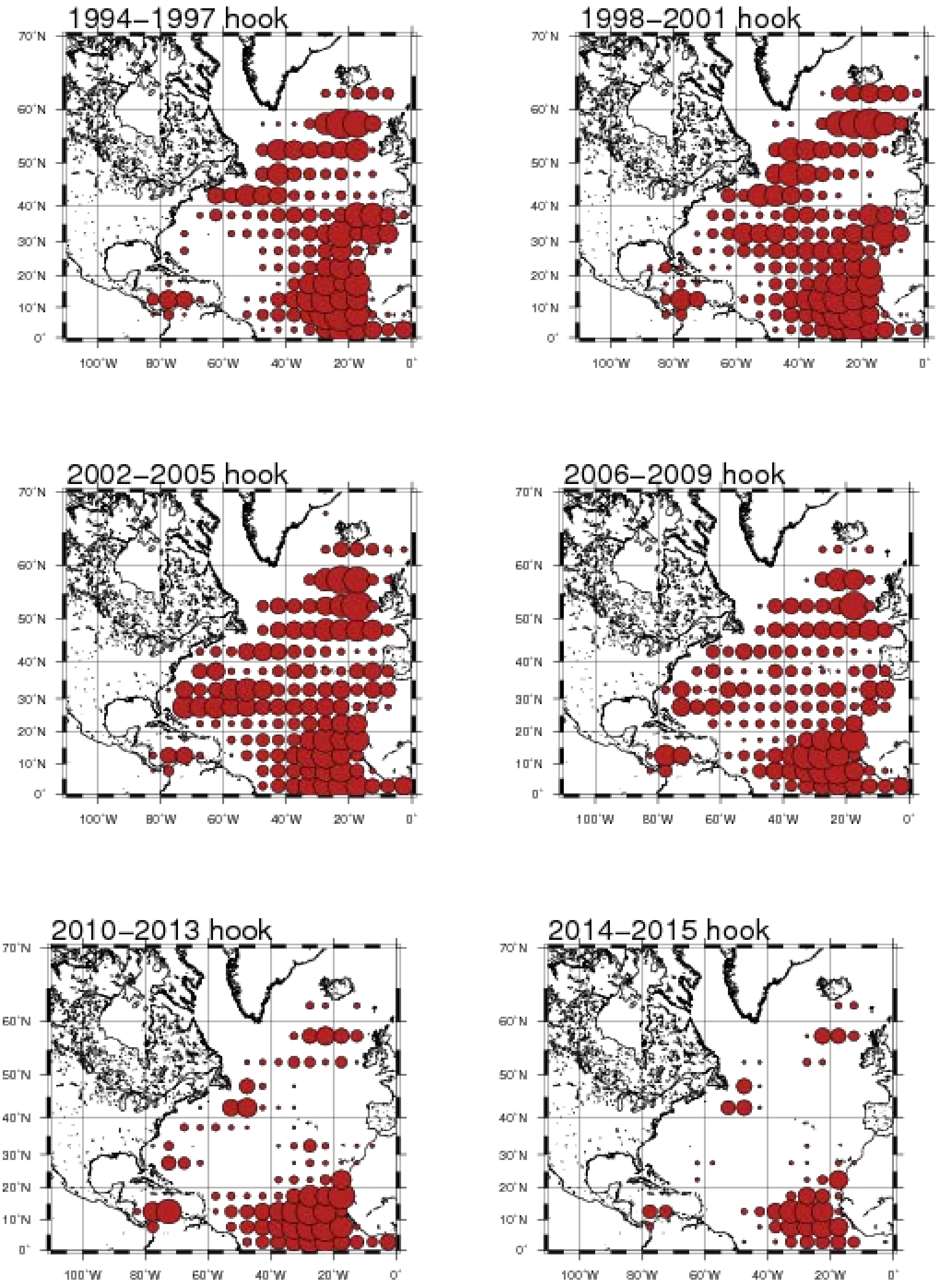


Figure 1. Temporal change in the distribution of effort for Japanese tuna longline fishery in the North Atlantic between 1994 and 2015. Each circle denotes the total number of hooks aggregated in 5 by 5 grid.

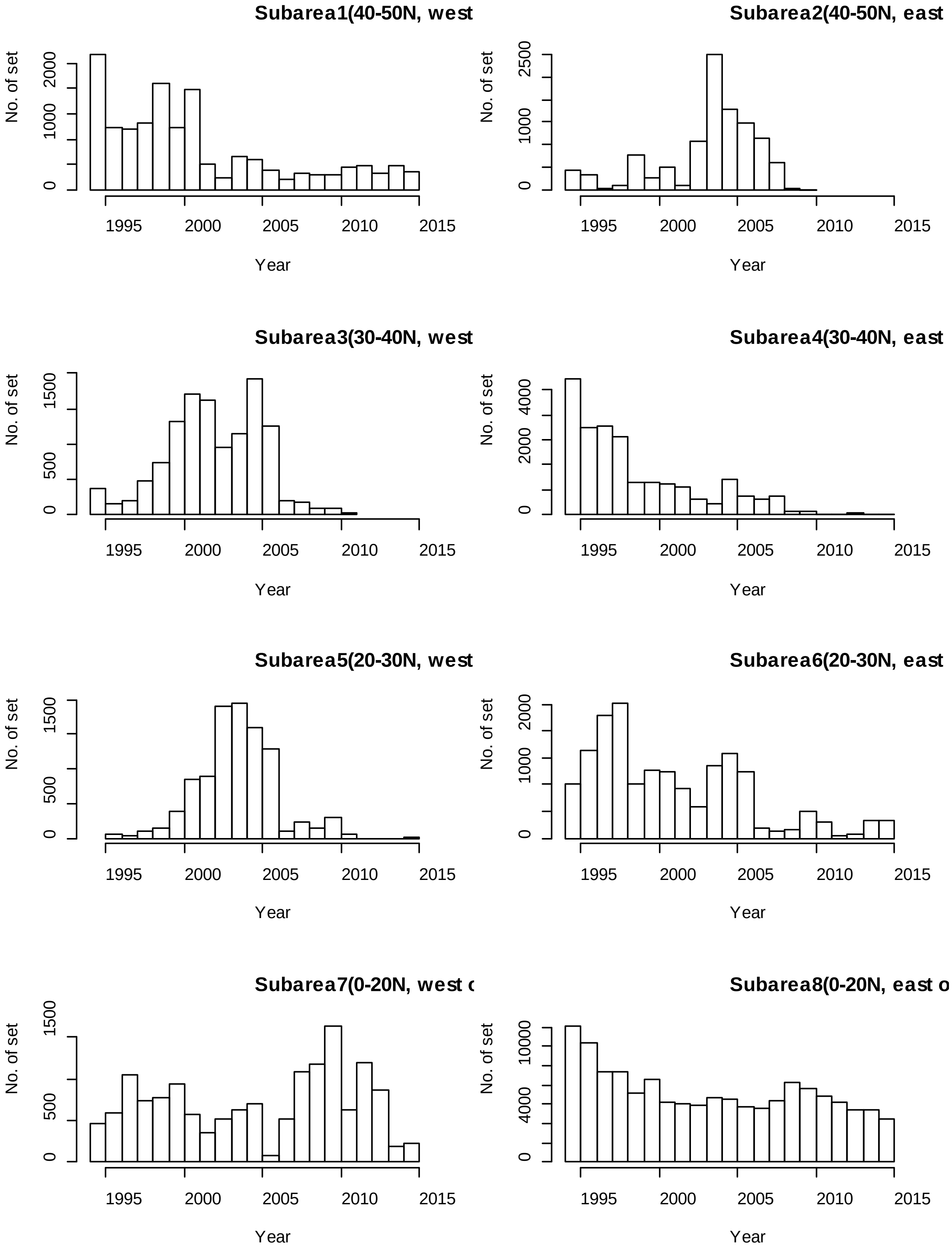


Figure 2. Annual changes in the number of set in 8 subareas in the North Atlantic. All figures were constructed based on the logbook data before filtering.

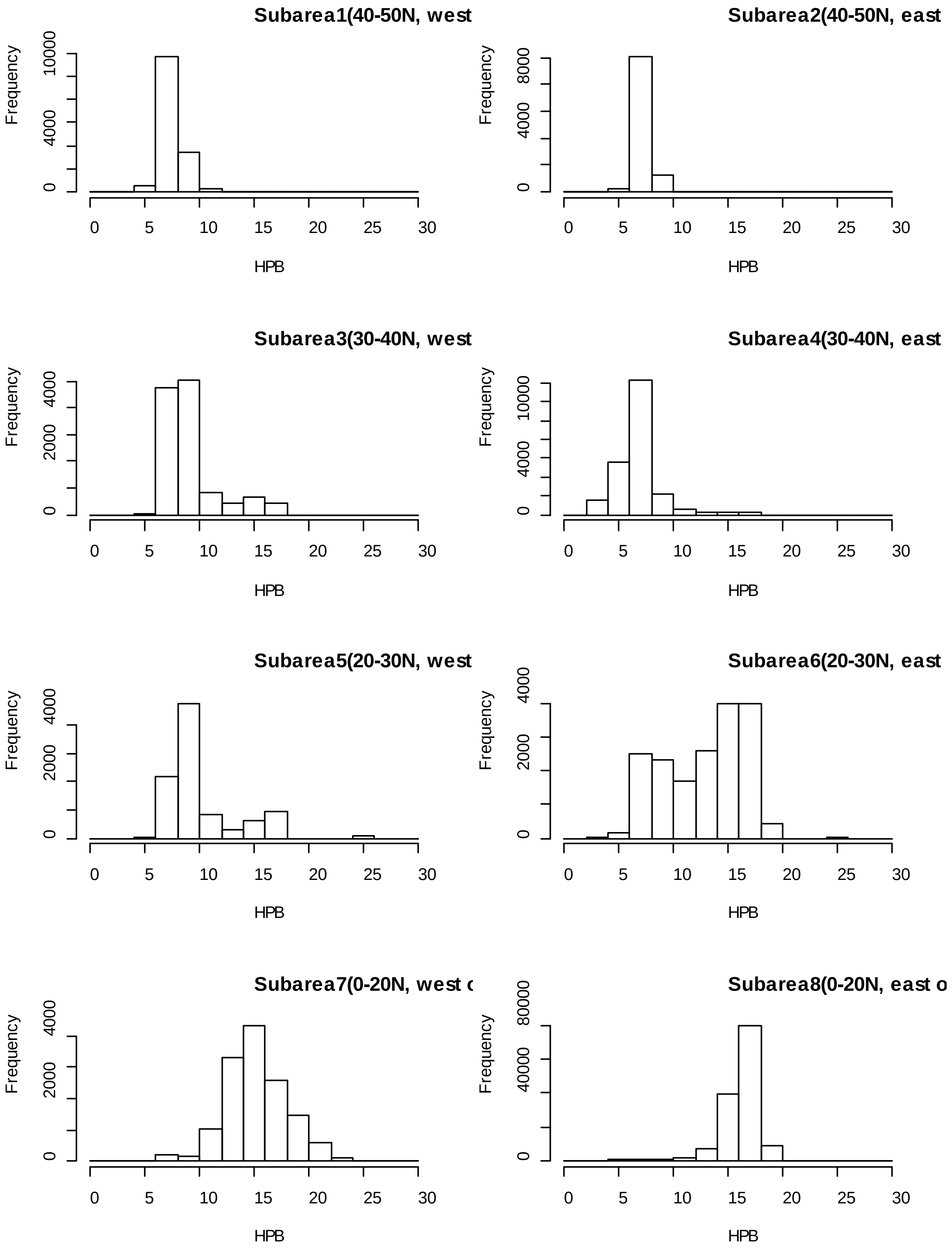


Figure 3. Distribution of HPB (number of hooks per basket) in 8 subareas in the North Atlantic. All figures were constructed based on the logbook data after data with extremely small and large HPB was filtered.

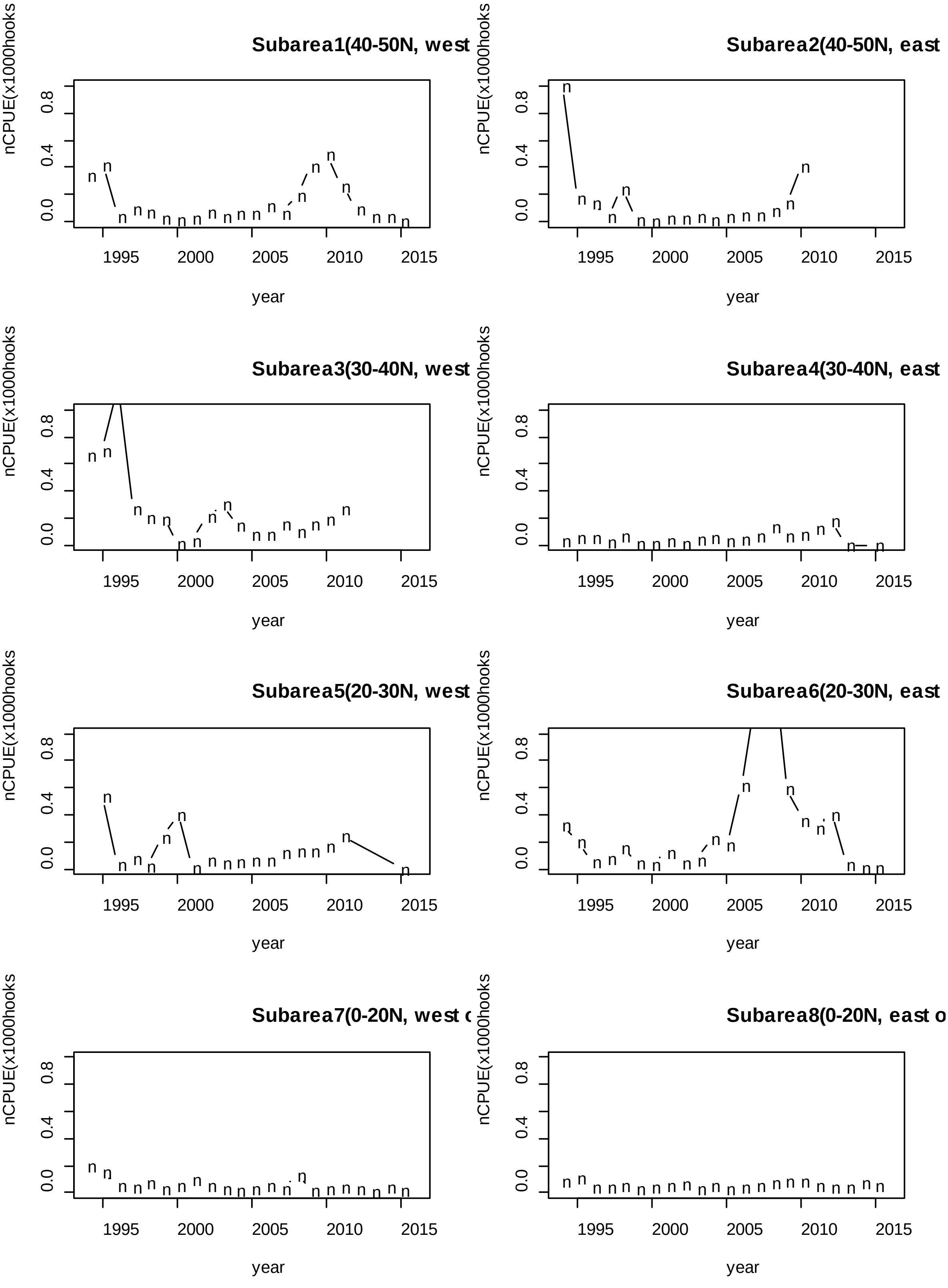


Figure 4. Nominal CPUE of shortfin mako by 8 subareas in the North Atlantic. All figures were constructed based on the logbook data before filtering.

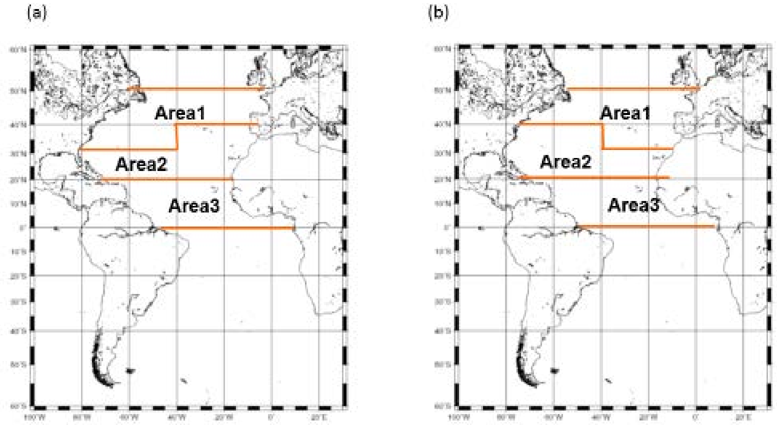


Figure 5. Area stratification used in (a) Semba *et al*. (2016) and (b) the current document.

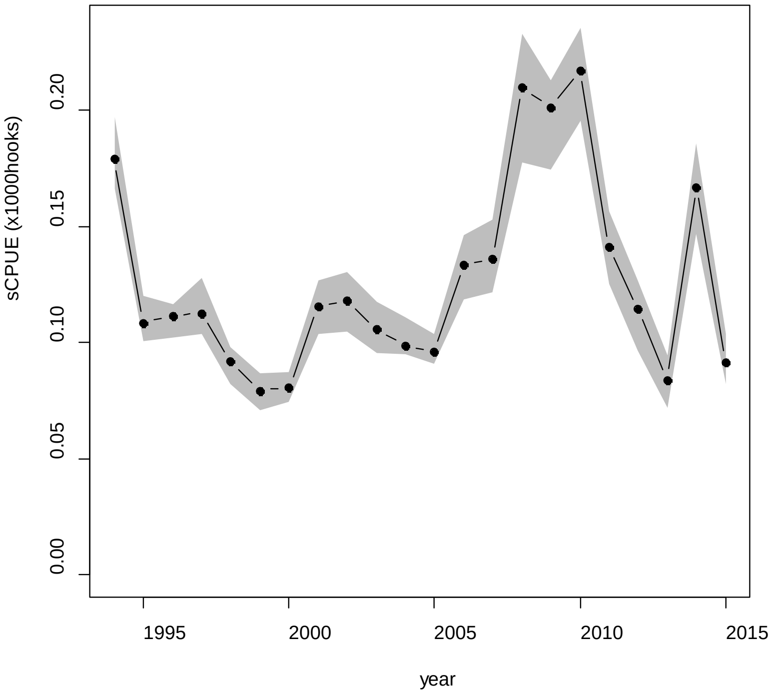


Figure 6. Abundance index of shortfin mako, estimated using logbook data of Japanese longliners in the North Atlantic. Filtered catch and effort data was used for the analysis and ZINB was applied for the standardization.

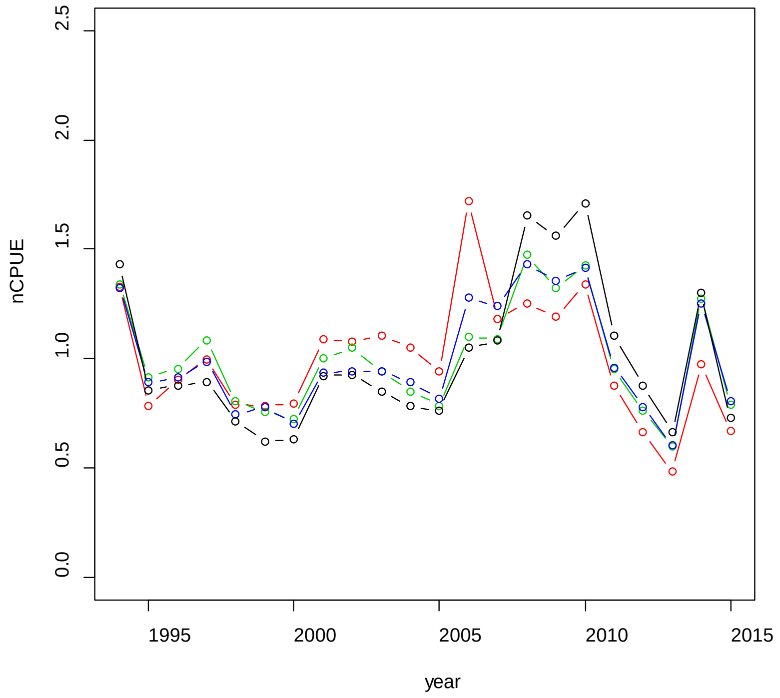


Figure 7. Normalized CPUE for nominal (red), NB (green), ZIP (blue), and ZINB (black). Nominal CPUE was calculated based on the filtered data.

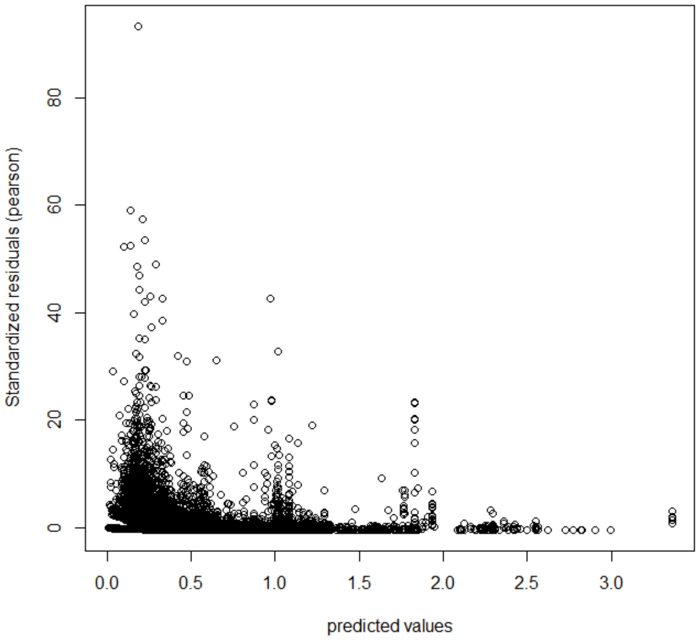


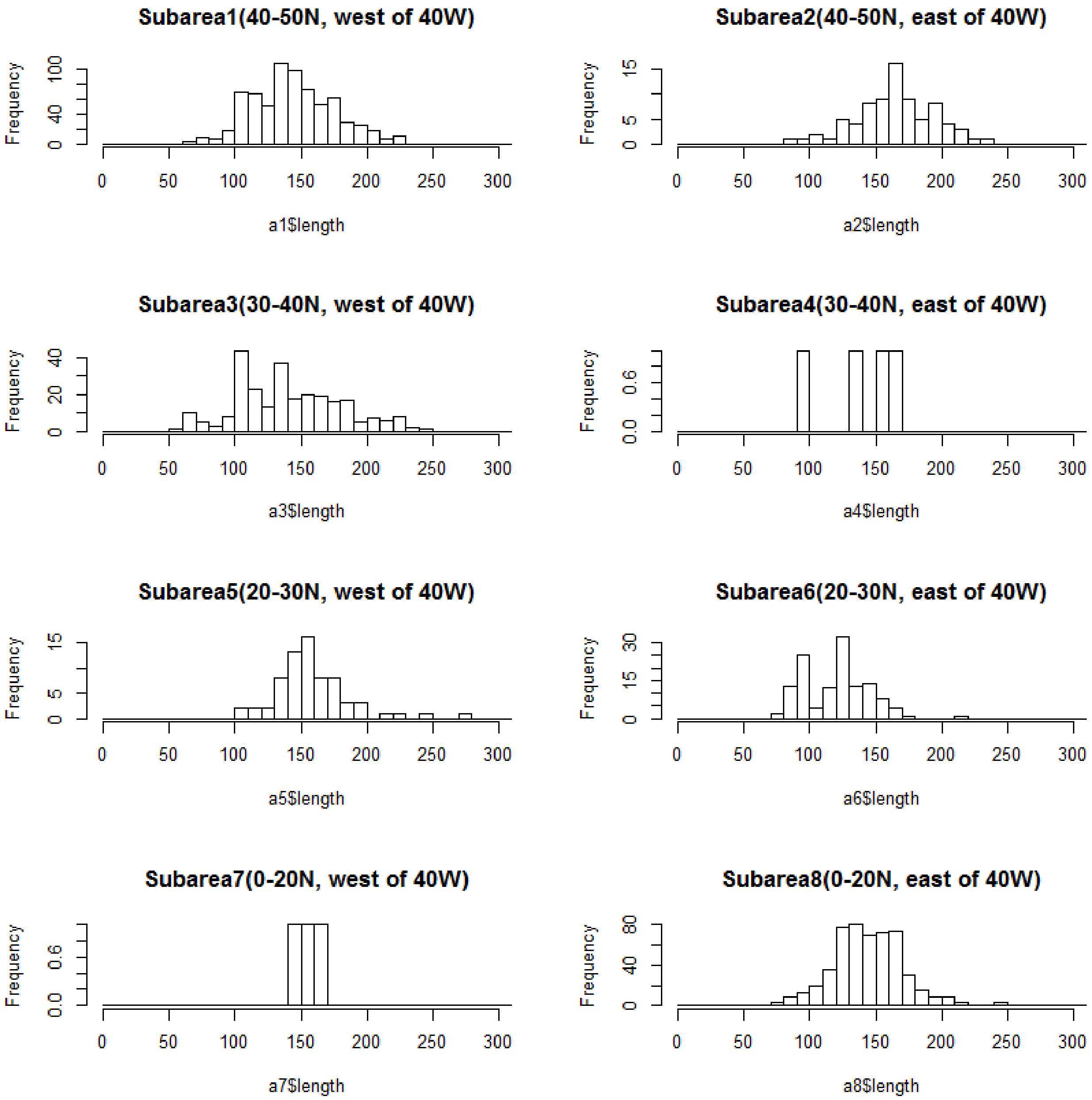
Figure 8. Plot of standardized residuals and fitted value for the zero-inflated negative binomial GLM.Appendix. Distribution of observation by every combination of covariates; (top left) year-area, (top right) year-quarter, (middle left) year-gear, (middle right) quarter-area, (bottom left) gear-area, and (bottom right) quarter-gear.

Appendix 1

Distribution of observation by every combination of covariates; (top left) year-area, (top right) year-quarter, (middle left) year-gear, (middle right) quarter-area, (bottom left) gear-area, and (bottom right) quarter-gear

Appendix 2

Size frequency of shortfin mako based on Japanese observer data collected in the North Atlantic between 1997 and 2016


Subarea1(40-50N, west of 40W)

Subarea2(40-50N, east of 40W)

Subarea3(30-40N, west of 40W)

Subarea4(30-40N, east of 40W)

Subarea5(20-30N, west of 40W)

Subarea6(20-30N, east of 40W)

Subarea7(0-20N, west of 40W)

Subarea8(0-20N, east of 40W)