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THE STANDARDIZED BLUEFIN CPUE OF JAPANESE LONGLINE FISHERY IN THE ATLANTIC UP TO 2017 FISHING YEAR

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SUMMARY

Abundance indices of bluefin tuna from the Japanese longline fishery in the West and Northeast Atlantic were provided up to 2017 fishing year. The indices were standardized with delta-lognormal model with random effect. Both in the West and Northeast Atlantic, fishing activities, the size of bluefin caught, and CPUE in the latest year were similar to the previous year. The standardized CPUE in the West Atlantic since 2011 fishing year remained at a relatively high level compared to those in the 1990s and early 2000s, and the historically highest values were observed in 2016FY and 2017FY. Abundance index in the Northeast Atlantic remained at a very high level (over 6 fish per 1000 hooks) since 2012 fishing year. The high CPUEs both in the West and Northeast Atlantic have been supported mainly by the strong 2003-year class and the following year classes. This strong year class already started to migrate into the spawning areas, and it would be beneficial to monitor the other fisheries which target larger fish both in the West and East stocks. It was noted that careful considerations would be needed for the use of Japanese CPUE series in the stock assessment of both west and east stocks.

RÉSUMÉ

Les indices d'abondance de la pêcherie palangrière japonaise ciblant le thon rouge et opérant dans l'Atlantique Ouest et Nord-Est ont été fournis jusqu'à l'année de pêche 2017. Les indices ont été standardisés au moyen d'un modèle delta-lognormal avec effet aléatoire. Dans l'Atlantique Ouest et Nord Est, les activités de pêche, la taille des thons rouges capturés et la CPUE de la dernière année étaient similaires à celles de l'année antérieure. Les CPUE standardisées dans l'Atlantique Ouest depuis l'année de pêche 2011 sont demeurées à un niveau relativement élevé par rapport à celles des années 90 et du début des années 2000, mais les valeurs historiques les plus élevées ont été observées pendant les années de pêche 2016 et 2017. L'indice d'abondance dans l'Atlantique Nord-Est est demeuré à un niveau très élevé (plus de six poissons pour 1.000 hameçons) depuis l'année de pêche 2012. Les CPUE élevées tant dans l'Atlantique Ouest que Nord-Est ont été soutenues principalement par la forte classe d'âge de 2003 et les classes d'âge suivantes. Cette forte classe annuelle a déjà commencé à migrer dans les zones de ponte et il serait judicieux d'effectuer un suivi des autres pêcheries qui ciblent des poissons plus grands dans les stocks Ouest et Est. Il a été noté qu'il conviendrait de faire preuve de prudence en utilisant cette série de CPUE japonaise dans l'évaluation des stocks de l'Est et de l'Ouest.

RESUMEN

Se facilitan índices de abundancia de atún rojo de la pesquería palangrera japonesa en el Atlántico occidental y nororiental hasta el año pesquero 2017. Los índices se estandarizaron mediante un modelo delta-lognormal con efectos aleatorios. Tanto en el Atlántico occidental como nororiental, las actividades pesqueras, la talla del atún rojo capturado, y la CPUE del último año eran muy similares a los del año anterior. La CPUE estandarizada en el Atlántico occidental desde el año pesquero 2011 permanecía en un nivel relativamente elevado en comparación con las de los 90 y principios de los 2000, y los valores históricamente más altos se observaron en los años pesqueros 2016 y 2017. El índice de abundancia en el Atlántico nororiental permaneció en un nivel muy elevado (más de seis peces por 1000 anzuelos) desde el año pesquero de 2012. Las CPUE elevadas en el Atlántico oeste y noreste se han visto respaldadas principalmente por la fuerte clase anual de 2003 y de los años siguientes. Esta fuerte clase anual empezó a migrar a zonas de reproducción, y sería beneficioso hacer un seguimiento de otras pesquerías que se dirigen a peces más grandes tanto en los stocks del este como del

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oeste. Se observó que se requerirá una consideración minuciosa al utilizar estas series japonesas de CPUE en la evaluación de stock, tanto de los stocks del este como del oeste.

KEYWORDS

Bluefin tuna, stock abundance, catch and effort, CPUE standardization, delta-lognormal model, Generalized Linear Mixed Model, long lining, size

Introduction

Japanese longline fishery data in the North Atlantic are valuable information for studying the bluefin tuna stock in the Atlantic. This fishery covers wide geographical areas in the North Atlantic and the Mediterranean Sea, where bluefin tuna were distributed, for more than five decades (Kimoto *et al*., 2015). This wide temporal/spacious coverage, together with a good accurate quality of the data is the most important advantages in providing reliable abundance trend for this species.

However, the patterns and areas of fishing by the Japanese longline fishery changed through the history especially in the recent 10 years (**Figures 1 and 2**), due to the introduction of IQ (individual vessels quota) and limited entry system to the Japanese longline vessels, voluntarily since August 2007 and by law August 2009 (Japan, 2011). Because both the amount of catch and the number of vessels have been significantly reduced, the Japanese longline fishery is not a major fishery for bluefin anymore. Although the abundance indices from this fishery are still very reliable and useful, it is strongly recommended to develop valid and reliable indices for other major fisheries (e.g. Mediterranean purse seine) while continued effort in improving Japanese longline standardized CPUE index is also desirable.

The abundance indices for the Eastern and the Western bluefin stocks have been given in the previous studies (Oshima *et al*., 2008 and 2009, Kimoto *et al*., 2011b, Kimoto *et al*., 2013b, and Kimoto *et al*., 2014, 2015, 2016a and 2016b). This paper provides the standardized CPUE for Atlantic bluefin tuna up to 2017 fishing year (FY: e.g. 2017FY refers to the period from August 1, 2016 to July 31, 2017). In this document, we have tried to incorporate sea surface temperature (SST) information in the standardization, and ran the model selection process for factor inclusion. In the east of 45°W, the Japanese longline vessels almost limited their operations solely in the Northeast Atlantic and rarely in the East Atlantic (off Gibraltar and Mediterranean) since 2010FY, due to the IQ system and the small quota for each vessel (**Figures 1 and 2**). Therefore, the CPUE series were updated to 2017FY in the West (1976-2017FY) and Northeast Atlantic (1990-2017FY), whereas the CPUE in the East Atlantic was not updated since 2010FY. The CPUE series were standardized by application of Generalized Linear Mixed Modeling technique.

Materials and methods

The catch and effort data (individual operation data) of the Japanese longline fishery were obtained from the logbook data compiled by the National Research Institute of Far Seas Fisheries (NRIFSF), and used for the CPUE standardization for the period from 1975 to 2016 fishing years. The fishing years were used in this report; 2016FY refers to the period from August 1, 2015 to July 31, 2016. Information on the number of hooks between floats (NHBF) is available since 1975 (indicative of the depth of the line). The catch history by the Japanese longline fishery dates back to much earlier period (back to 1958) but the catches before the mid-1970s mostly came from different areas (mostly tropical waters) from the current fishing grounds. In addition, there were no reliable and sufficient size data available for them. It should be noted that the fleets are very mobile and their operational practice and fishing techniques have been constantly modified during its history (Miyake *et al*, 2010).

In addition to the above logbook data, the operational data from daily report in the most recent fishing year, 2017FY, were included for the standardization. In August 2008, Fishery Agency of Japan started the daily reporting system to tag of the individual bluefin tuna caught by the Japanese longliners (for identification) and collect their weight (Japan, 2011). Since 2016 FY, total hooks and the number of baskets have been also collected in this system. In 2017 FY, the period from August 1, 2016 to July 31, 2017, the Japanese longliners already finished their quota for both eastern and western Atlantic bluefin tuna, thus all operational data were compiled. These data are mostly equivalent to the logbook data, except the information on the materials of main and branch lines for the standardization. For modelling, those informations were assumed to be equal to the operations in adjacent years by the same vessel.

The SST were incorporated in the standardization, and the NOAA_OI_SST_V2 data were provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/ in any documents or publications using these data.

The CPUE were standardized respectively for the traditional two areas by applying the same model as previously described by Kimoto *et al.* (2010b, 2012b, 2013, 2014, 2015, and 2016). These two areas are West Atlantic (off US and Canada, north of 30°N and west of 45°W), and Northeast Atlantic (off Iceland north of 40°N and east of 45°W). The area definitions are shown in Figures 3 and 4. Total accumulative numbers of observations (set by set data) throughout the period to 2017FY considered for the standardized CPUEs are 80,872 in the West Atlantic (**Table 1**), and 86,841 in the Northeast Atlantic (**Table 2**), after eliminating some anomalies due to a technical error.

In the West Atlantic, the introduction of strict IQ system may have affected to the skipper's behaviors since 2010FY, and they gradually started to operate in August and preferred to finish their quota by December (**Table 1**). They target principally bluefin, and sometimes bigeye and/or swordfish at the same time. In the traditional CPUE standardization, the operational data between November and February in the north of 30N and the south of 50N have been used because the duration was the main fishing season for bluefin (**Tables 1 and 4**), thus a substantial portion of data before October are not included in the analyses since 2010FY. Especially in 2017FY, there were only 9 operations in those month and areas. To improve this CPUE series, the historical fishing pattern in October were checked to incorporate into the model. In October, Japanese longliners sometimes caught bluefin tuna, but there are not many operations compared to the main fishing seasons after November. The pattern of CPUE in October was not very different from one in November. Thus, it was decided to include the data in October specially to improve the CPUE in the most recent 5 years.

The size measurement (or composition) data for bluefin tuna caught by the Japanese longline fishery have been collected through the research programs by the NRIFSF and observer program by the Fishery Agency of Japan (Kimoto et al., 2011a). Therefore, converted size (length) data, using weight-length relationship by ICCAT (Anon, 2011), are available for all fish caught from 2009FY. The number of available size data is shown in **Table 3**. Applying slicing procedures to the size frequencies of bluefin caught by the Japanese longliners, catch at age was estimated for 2009 through 2013FYs from the converted size data. For slicing, the von Bertalanffy growth function estimated by ICCAT (Anon, 2011) was used.

Standardized CPUE to 2017FY for the West and Northeast Atlantic

In the CPUE standardization, fishing year, month, area, SST, main and branch line material, and the number of hooks between floats were considered as main effects in the model, and interactions between month and area were included as a random effect. The original area stratification of each index was shown in Figure 3. Information on materials for main and branch lines is only available since 1994 and classified as either nylon or other materials. The lines used before 1994 were assumed as other materials. In order to keep the interaction in the model (avoiding lack of observations), some adjacent categories (month and area) were aggregated (Figure 4). Categories in each main effect adopted in the model are shown in Table 4-a. Delta-lognormal model (Lo et al., 1992) with binomial distribution to model successful/unsuccessful sets and lognormal for positive catch rate was applied for standardizing CPUE, because the data set includes many zero-catch observations. Model formula of logistic regression model of the 1st step model is as follows,

$$\log \frac{p}{1-p} = \text{Intercept} + (\text{Main effects}) + (\text{Interaction term}) \quad (1)$$

where Log(p/(1 − p)) is logit link function, p indicates ratio of positive catch set and is assumed to binomially distributed. The model formula of lognormal model of the 2nd step is as follows,

$$\text{logCPUE} = \text{Intercept} + (\text{Main effects}) + (\text{Interaction term}) + \text{Error} \quad (2)$$

where logCPUE indicates natural logarithm of catch rate of positive set, that is the number of bluefin tuna per 1000 hooks, and error is also assumed to be distributed normally. The fitting was conducted by GLIMMIX macro and MIXED procedure of SAS/STAT package (Version 9.4) for the 1st and 2nd steps, respectively. Model selection was performed by systematic reduction of model terms until obtaining the smallest AIC in the 1st and 2nd steps.

In the Northeast Atlantic, the model of the 1st step was not converged with the data after 2013FYs, because the ratios of positive catch were 1.0 or very close to 1.0 in these fishing years (**Figure 5**). To avoid the convergence problem, the model of the 1st step was estimated up to 2012FY without these FYs, and the output in the 2nd step since 2013FY were directly use for the standardized CPUE. In the West Atlantic, 1.0 positive catch ratio was observed in 2017FY, thus the same technique was adopted.

Results and discussion

It is essential to have reliable adult abundance indices from this fleet for successful stock assessment of Atlantic bluefin tuna stocks. Main purpose of this work is to provide the updated standardized CPUE by Japanese longline vessels up to 2017FY in the West and Northeast Atlantic. However, this document continuously highlighted the substantial difficulty to provide reliable indices of abundance of adult bluefin tuna both in the West and Northeast Atlantic. This is primary due to a steep decline of the number of set available to the analysis. This decline of observations in the Northeast Atlantic was caused by the total TAC reduction as well as recent increase of the stocks. Since 2012, each longline vessel finished their quota within 20 days on average. The decline in the West Atlantic was caused by the change of operating season as well as recent increase of the stocks. For the traditional CPUE standardization in the West Atlantic, the results were obtained from 7-50% of total number of operations since 2014FY. Current quota available to this fleet is not sufficient to maintain continuous CPUE capable to detect the abundance trend.

In this document, SST were newly considered in the model, and model selection was performed by systematic reduction of model terms until obtaining the smallest AIC in the 1st and 2nd steps. Results of model selection were shown in Table 5, and the simpler model was chosen for the positive catch ratio (first step) for both West and Northeast Atlantic. The same model for logCPUE with positive catch (second step) for both areas were chosen. And the variable of branch line material was excluded in the final model from the full model. Results of type III test for positive catch ratio (1st step) and CPUE of positive catch (2nd step) in the final models were shown in **Tables 6.**

The final models of 1st and 2nd steps are as follows,

West Atlantic

$$\log \frac{p}{1-p} = \text{Intercept} + \text{Year} + \text{Month} + \text{Area} + \text{Main} + Month * Area \quad (3)$$

$$\text{logCPUE} = \text{Intercept} + \text{Year} + \text{Month} + \text{Area} + \text{NHBF} + \text{Main} + Month * Area \quad (4)$$

where the interaction term was included as random effect.

Northeast Atlantic

$$\log \frac{p}{1-p} = \text{Intercept} + \text{Year} + \text{Month} + \text{Area} + Month * Area \quad (5)$$

$$\text{logCPUE} = \text{Intercept} + \text{Year} + \text{Month} + \text{Area} + \text{NHBF} + \text{Main} + Month * Area \quad (6)$$

where the interaction term was included as random effect.

Model diagnostics for the West and Northeast Atlantic for the final models were shown in **Figures 6 and 7**, respectively. These diagnostics were similar to those what the previous standardized CPUE series had. Residual patterns of positive CPUE in the 2nd step were slightly skewed to the right in these areas (**Figures 6 and 7, a-d**). Additionally, the residual distribution in the Northeast Atlantic had two modes. There were large annual fluctuations in observed and predicted proportions of positive catch in the West Atlantic (**Figure 6-e**), while the proportions in the Northeast Atlantic showed less fluctuations compared to that in the West (**Figure 7-e**). Especially in 2016 and 2017 FYs in the West Atlantic, the observed positive catch ratio recorded 0.98 and 1.00, while it has been in the range between 0.5 and 0.7 since 1975FY (**Figure 6-e**). In the Northeast Atlantic, the positive catch ratio since 2010FY were also high and has been over 0.98 (**Figure 7-e**).

Observed CPUE of positive catch in the West Atlantic fluctuated without any trend during 1976-2017FY, and it jumped up sharply in 2007, 2011, 2016 and 2017FYs (**Figure 6-f**). On the other hand, the CPUE in the Northeast Atlantic were stable until 2008FY except for 1996FY, demonstrated an upward trend since 2010FY, and remained at very high levels compared to those in previous years (**Figure 7-f**).

Standardized CPUE based on the Least Square Mean are shown in **Figure 8** (**Figure 9** in logarithmic scale) and **Table 7**. In the West Atlantic (**Figure 8-a**), the abundance indices showed gradual decline with large fluctuations from 1976FY to the mid-1980s, having reached the lowest in 1986FY. It recovered since then and showed relatively stable until the mid-2000s except for the sudden increase in 1996FY. It exhibited an increase after 2005FY remained at a relatively high level since 2011FY with large fluctuations. The sharp decline was observed in 2010FY which was probably caused by the change of their main fishing ground and many zero catch data (**Figure 6-e**), which may be related to a good catch rate of bigeye tuna by targeting bigeye rather than bluefin. Only in 2010FY, the longline vessels mostly operated in the south part (25-35°N and 65-75°W) of which was outside of the defined area for the standardization, and hence large portion of data are not included in the analyses.

The standardized CPUEs since 2011FY were relatively high and possibly related to the good catch of 2003 and the following year classes. The nominal CPUE values of some sets since 2011FY in the West area were as high as those observed in the Northeast, and the size range of fish in the main fishing area and season (40-45°N, 45-55°W, November and December) being similar to those in the Northeast Atlantic (50-60°N and 15-35°W, October to November). The historically highest values were observed in 2016 and 2017 FYs with the good catches of these year classes. The confidence intervals in these years were very wide, however this is mainly due to the magnitude of CPUE and they were slightly wider in log-scaled (**Figure 9-a**). This information may support the stock recovery in the west Atlantic.

The comparison of the standardized CPUE in the West Atlantic with and without October data were shown in Figure 10, and the trend generally was not changed except in 2014, 2016 and 2017FYs. Those three years did not have many observations in between November and February (**Table 1**). Incorporating set by set data in October improved the standardization, and the ranges of standard errors on the coefficient on the term of fishing year became 0.95~1.18 with the data in October from 1.61~1.83 without the data in October for the 1st step and 0.29~0.38 from 0.46~0.58 for the 2nd step. It was confirmed that the data in October provided better estimations especially in the most recent 5 years.

In the Northeast Atlantic (**Figure 8-b**), standardized abundance indices have been relatively stable until the mid-2000s except for the sudden increase in 1996FY. It started increasing in 2009FY, reached the highest value in 2012FY, and remained at a high level since then. The confidence intervals in the recent years were very wide, however this is mainly due to the magnitude of CPUE and they were slightly wider in log-scaled (**Figure 9-b**). Since 2010FY, the high CPUEs were observed in October and November, in the northern areas: 50-60°N and 15-35°W (**Figure 1 and 2**), where and when the most of the operations are concentrated, because the fish of high quality and value are obtained. Those concentrated operations may also affect the width of the confidence intervals with the high observed CPUEs.

It should be noted that the Japanese longline catch between 2010 and 2015 FYs were consisted mainly of 2003-year class (**Figures 11 and 12**), while they already appeared in 2009FY catch. Since 2014FY, the following year class, around 2007 year-class, has started to contribute to the longline catch, and they became majority of catch since 2016FY. Considering the high CPUE since 2016FY, the following year classes seem to be also abundant. However, the current high CPUEs might be also related to the increased skipper's efficiency. The fishing season has been shortened since 2011 FY (**Table 2**) and the average fishing days of each vessel were less than 20 days, because the body weight of bluefin tuna caught increased with very high catch rate in the same quota and/or even in the slight increased quota. Hence the amount of catch can quickly reach to the individual quota given the current small quota. Under the current small quota, the continued high CPUEs will remain the total fishing efforts reduced substantially and will result in the substantially limited temporal/spatial coverage of efforts. The uncertainty in the stock assessment results could increase. It would be desirable to have more observations (longline sets) to monitor the abundance of bluefin tuna in the Northeast Atlantic in the wide area that had been observed before 2008FY. Currently observed high CPUEs with limited number of longline sets, hence very limited spatial and temporal coverage may possibly over- or under-estimates the year class strength.

The strong 2003-year class is gradually disappearing from the fishing ground of Japanese longline off Iceland, while they are still main catches in the west Atlantic, off Canada. The good CPUEs were already observed in other fisheries (Anon. 2013 and 2015) both in the West and East Atlantic. It is reported that this year class already started to migrate into Mediterranean (Gordoa, 2014 and 2015). The similar phenomenon may affect the CPUE series targeting large fish in the spawning area, and the careful attention would be necessary. It is strongly encouraged to continue to collect more size information and monitor the situations in both spawning grounds. The information will lead to further understandings of biology of Atlantic bluefin tuna, and to the reduction of the uncertainties in the stock assessment and management.

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Table 1. Number of longline sets by various strata for the West Atlantic CPUE standardization. Observations were aggregated by month, area (prefixed by A), materials of main line (M1=others, M2=nylon) and branch line (F1=others, F2=nylon), number of hooks between floats (prefixed by B). Area definition is shown in Figure 3. Year is fishing year (2017 means August 2016 to July 2017).

Year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16
1976	69	112	143	347	322	266	208	10	20	0	0	0	0	0	4	356	223	8	0	0	0	15	282
1977	426	497	588	534	522	519	212	52	55	1	0	0	0	0	33	656	869	192	0	0	0	15	159
1978	34	96	343	516	559	377	45	0	18	0	1	0	0	0	15	395	249	95	0	2	0	5	24
1979	126	218	591	755	680	749	179	4	26	0	0	0	0	0	41	516	819	132	1	23	11	9	183
1980	223	358	644	824	777	683	170	0	103	1	0	0	0	0	0	332	341	142	55	0	3	6	79
1981	270	601	1201	1513	1512	902	341	0	7	0	0	0	0	0	0	710	583	470	220	10	3	38	367
1982	915	1333	2236	1753	846	206	116	0	11	1	3	1	0	0	0	1171	831	407	59	1	0	83	561
1983	387	433	561	891	694	623	504	0	5	1	0	0	0	0	0	355	465	245	12	0	0	94	256
1984	90	138	314	629	624	572	212	0	1	0	0	0	0	0	0	62	324	86	9	1	2	0	67
1985	25	45	310	723	851	655	344	0	0	0	0	0	0	0	0	94	394	66	6	0	1	3	197
1986	176	239	420	688	641	551	53	0	0	0	0	0	0	0	0	33	234	88	5	36	13	0	52
1987	293	445	658	897	944	710	42	0	41	26	0	21	7	0	0	9	339	288	1	0	0	0	194
1988	281	414	751	891	869	651	364	0	1	0	0	0	10	0	0	54	618	591	42	11	0	0	337
1989	149	291	517	804	1051	521	247	0	19	54	129	347	51	3	0	3	202	491	6	0	0	0	128
1990	85	161	589	663	782	766	296	0	0	5	59	311	84	1	0	0	112	234	42	19	7	0	60
1991	0	143	351	516	479	502	154	0	0	0	17	68	123	6	0	0	15	24	40	5	0	0	103
1992	30	132	281	310	667	392	2	0	1	0	8	43	21	3	0	4	26	9	1	10	0	0	24
1993	16	57	311	664	622	343	53	0	0	0	0	0	0	0	0	0	12	53	3	2	0	0	14
1994	0	6	156	336	575	533	92	0	0	0	0	0	0	0	0	0	17	9	9	26	0	0	6
1995	0	50	389	235	217	112	1	0	0	0	0	11	11	0	0	0	15	78	10	0	1	0	0
1996	0	0	0	38	371	70	0	0	11	0	0	0	0	2	0	0	0	11	0	0	0	0	24
1997	0	0	16	73	613	133	0	0	0	0	0	6	34	28	0	0	0	3	0	0	3	0	7
1998	0	0	6	31	747	375	33	0	0	17	0	26	5	0	0	0	8	79	1	3	30	0	0
1999	51	9	10	316	585	244	127	0	0	3	90	91	40	74	0	0	23	3	5	2	3	0	0
2000	11	25	47	347	565	201	153	0	0	0	23	93	32	172	0	0	2	5	0	0	1	0	1
2001	129	112	72	190	672	221	134	0	0	1	67	345	123	198	0	0	3	6	3	2	0	0	0
2002	22	31	68	638	837	320	395	0	22	7	97	265	425	140	0	0	27	29	0	7	10	0	0
2003	0	4	32	163	442	57	106	0	87	10	7	141	37	86	0	0	0	0	0	3	13	0	0
2004	1	10	11	41	156	461	167	0	72	2	52	137	72	47	0	0	30	42	5	1	0	0	0
2005	0	0	9	10	214	790	761	5	195	0	107	135	108	28	0	0	543	124	5	1	5	0	20
2006	0	10	14	0	136	561	368	18	121	4	73	181	154	37	0	0	38	165	2	0	0	0	1
2007	0	0	0	6	83	132	149	42	76	0	0	0	0	0	0	0	69	21	7	1	0	0	0
2008	0	4	0	0	55	143	40	81	121	0	0	0	0	0	0	0	1	1	0	0	0	0	0
2009	4	0	0	7	29	18	0	4	12	0	0	0	0	0	0	0	2	1	0	0	0	0	0
2010	12	80	84	89	51	6	0	1	41	10	0	0	0	0	0	0	2	8	0	1	1	0	0
2011	42	49	87	99	100	84	2	11	26	0	0	0	0	0	0	2	17	5	13	1	0	0	0
2012	15	98	104	102	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
2013	14	108	119	121	108	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	15	143	125	47	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	20	91	132	120	126	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	6	138	131	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	50	62	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3937	6731	12483	17016	20181	14454	6070	228	1092	143	733	2222	1337	825	93	4752	7453	4211	562	168	108	268	3146

Table 1. Continued.

Year	A17	A18	A19	A20	A21	A22	A23	A24	M1	M2	F1	F2	B5	B6	B7	B8	B9	B10	B11	B12	B13	Total
1976	26	13	463	32	0	0	3	12	1467	0	1467	0	1199	268	0	0	0	0	0	0	0	1467
1977	238	192	671	162	0	0	0	3	3298	0	3298	0	2670	619	0	9	0	0	0	0	0	3298
1978	186	78	876	24	0	0	2	0	1970	0	1970	0	1764	203	0	0	0	3	0	0	0	1970
1979	481	91	804	143	0	0	0	14	3298	0	3298	0	2653	571	46	0	0	28	0	0	0	3298
1980	984	774	787	71	0	0	0	1	3679	0	3679	0	2958	616	50	28	24	3	0	0	0	3679
1981	1383	756	1464	300	0	0	0	29	6340	0	6340	0	3648	1540	459	178	149	252	86	28	0	6340
1982	1218	675	1950	396	0	0	0	37	7405	0	7405	0	2326	1926	423	371	415	1244	516	184	0	7405
1983	1119	365	1042	111	0	0	0	23	4093	0	4093	0	1024	1601	249	242	127	534	24	210	82	4093
1984	974	272	617	156	0	0	0	8	2579	0	2579	0	470	1700	144	20	17	138	61	6	23	2579
1985	583	193	1245	168	0	0	1	2	2953	0	2953	0	43	1527	1112	11	39	28	3	68	122	2953
1986	329	78	1531	348	0	0	0	21	2768	0	2768	0	21	869	1316	253	5	168	5	0	131	2768
1987	913	432	1408	255	0	0	2	53	3989	0	3989	0	77	1297	1997	383	91	38	0	106	0	3989
1988	1251	479	740	61	0	0	0	26	4221	0	4221	0	5	266	2921	487	78	265	26	64	109	4221
1989	630	651	698	141	0	0	1	26	3580	0	3580	0	20	383	2179	644	14	150	50	80	60	3580
1990	814	601	780	168	0	0	0	45	3342	0	3342	0	0	415	2122	532	26	207	0	40	0	3342
1991	466	184	824	172	0	0	11	87	2145	0	2145	0	43	147	1272	544	25	43	1	25	45	2145
1992	210	354	778	164	0	1	1	156	1814	0	1814	0	0	220	924	512	99	41	0	2	16	1814
1993	471	471	942	75	0	0	0	23	2066	0	2066	0	36	329	1151	369	109	46	20	6	0	2066
1994	316	267	752	286	0	0	0	10	1073	11	1073	72	27	192	1078	276	111	0	0	14	0	1698
1995	292	161	337	83	0	0	0	5	0	139	0	373	33	5	270	293	166	187	48	2	0	1004
1996	52	15	138	177	0	0	0	49	0	328	0	287	0	15	127	237	91	9	0	0	0	479
1997	61	29	258	188	0	0	0	218	0	726	0	630	1	22	169	357	131	53	68	0	34	835
1998	154	39	229	355	0	0	0	246	0	1036	0	1028	0	0	322	646	86	106	32	0	0	1192
1999	15	23	373	393	0	0	0	204	0	1263	0	1149	0	59	159	861	49	140	0	53	21	1342
2000	176	50	499	236	0	0	0	59	0	1310	0	1258	0	3	181	650	258	125	51	33	48	1349
2001	1	5	355	124	0	0	1	296	0	1524	0	1511	1	6	208	963	70	235	20	20	7	1530
2002	14	14	367	235	0	0	0	652	0	2241	0	2142	0	0	63	1493	384	213	2	127	29	2311
2003	2	5	120	209	0	0	0	84	0	804	0	804	0	0	28	366	260	85	1	64	0	804
2004	18	10	64	273	0	0	0	22	0	768	0	815	0	0	105	446	248	48	0	0	0	847
2005	42	91	179	195	0	0	0	1	0	1718	0	1555	0	2	12	711	925	73	0	32	29	1784
2006	119	17	73	72	0	0	0	14	0	1071	0	972	0	0	2	495	431	96	0	48	17	1089
2007	6	63	77	6	0	0	0	2	0	370	0	324	0	0	0	141	203	26	0	0	0	370
2008	12	3	14	8	0	0	0	1	0	199	0	189	0	0	0	26	216	0	0	0	0	242
2009	4	1	25	3	0	0	0	6	0	53	0	53	0	0	0	35	20	3	0	0	0	58
2010	0	30	135	58	0	0	0	35	0	322	0	322	0	0	0	248	60	10	0	4	0	322
2011	1	4	217	96	0	0	0	70	0	463	0	463	0	0	0	82	334	1	0	45	1	463
2012	0	2	200	145	0	0	0	25	0	373	0	373	0	0	0	207	164	0	0	2	0	373
2013	0	0	195	208	0	0	0	71	0	474	0	474	0	0	0	230	240	4	0	0	0	474
2014	0	2	41	144	0	0	0	146	64	269	0	333	0	0	0	194	134	5	0	0	0	333
2015	0	0	222	106	0	0	0	162	0	490	0	490	0	0	0	305	183	0	0	2	0	490
2016	0	0	77	130	0	0	0	148	0	355	0	355	0	0	0	214	141	0	0	0	0	355
2017	0	0	32	23	0	0	0	66	0	121	0	121	0	0	0	75	46	0	0	0	0	121
Total	13561	7490	22599	6700	0	1	22	3158	62144	16428	62080	16093	19019	14801	19089	14134	6169	4607	1014	1265	774	80872

Table 2. Number of longline sets by various strata for the Northeast Atlantic CPUE standardization. Observations were aggregated by month, area (prefixed by A), materials of main line (M1=others, M2=nylon) and branch line (F1=others, F2=nylon), number of hooks between floats (prefixed by B). Area definition is shown in **Figure 3**. Year is fishing year (2017 means August 2016 to July 2017).

Year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	A31	A32	A33	A34	A35	M1	M2	F1	F2	B4	B5	B6	B7	B8	B9	B10	B11	B12	Total
1990	0	0	21	136	245	155	56	6	613	0	6	0	0	619	0	619	0	0	6	304	230	38	30	11	0	0	619
1991	0	32	233	734	1100	312	86	25	2519	0	3	0	0	2522	0	2522	0	0	85	887	920	373	78	107	55	17	2522
1992	0	58	724	1738	1289	477	103	11	4288	97	15	0	0	4400	0	4400	0	79	170	2149	1409	443	34	91	0	25	4400
1993	16	341	1219	1366	869	323	39	0	1250	2592	77	254	0	4173	0	4173	0	29	93	3421	473	22	26	30	6	73	4173
1994	0	24	458	902	738	350	116	8	1438	1157	1	0	0	2122	21	2122	110	0	16	2079	365	5	0	0	0	131	2596
1995	0	105	282	646	459	108	18	0	254	259	232	873	0	0	348	0	791	0	68	740	419	278	113	0	0	0	1618
1996	61	610	1227	910	233	0	0	0	245	454	3	2339	0	0	2109	0	2061	0	0	156	1625	1065	195	0	0	0	3041
1997	122	2044	1660	1555	3	0	0	0	800	1062	45	3477	0	0	4499	0	4243	0	0	249	3004	1946	184	1	0	0	5384
1998	651	1469	2296	1849	6	0	0	0	251	928	8	5020	64	0	5596	0	5552	0	59	5	4351	1685	166	2	2	1	6271
1999	1163	1774	1878	614	90	3	0	0	177	692	4	4330	319	0	5139	0	4561	0	1	183	2452	2787	52	47	0	0	5522
2000	877	1510	1836	1594	1149	10	0	0	1802	939	79	3974	182	0	6415	0	6493	0	1	76	2685	3955	254	4	0	1	6976
2001	637	1230	1685	1679	105	88	49	59	741	1282	15	3447	47	0	5235	0	5206	0	0	49	2052	3128	196	31	5	71	5532
2002	473	1063	1623	806	67	23	21	7	908	678	22	2357	118	0	3895	0	3668	0	0	0	620	3307	143	3	10	0	4083
2003	270	941	1390	949	14	0	0	0	99	141	39	3255	30	0	3439	0	3370	0	1	1	333	2957	272	0	0	0	3564
2004	591	1233	1611	1513	1160	16	0	0	331	310	866	4615	2	0	5704	0	5764	0	0	1	706	4618	670	124	5	0	6124
2005	262	1113	1723	1947	1427	117	0	2	713	135	2569	3174	0	0	6229	0	5987	0	7	2	392	5231	910	49	0	0	6591
2006	256	826	1502	1514	1100	52	3	0	851	375	979	3048	0	0	5027	0	4661	0	0	0	366	3954	837	89	4	3	5253
2007	68	393	989	774	696	226	17	0	327	117	1396	1323	0	0	3040	0	2872	0	0	0	0	2943	220	0	0	0	3163
2008	51	482	790	665	539	204	5	0	313	48	848	1527	0	0	2659	0	2382	0	0	0	73	2639	24	0	0	0	2736
2009	186	731	872	846	384	33	0	0	444	534	229	1845	0	120	2854	120	2854	0	0	0	1	2720	325	6	0	0	3052
2010	0	217	789	429	46	1	0	0	23	87	5	1367	0	68	1288	26	1413	0	0	0	0	1373	109	0	0	0	1482
2011	0	16	488	178	0	0	0	0	1	95	0	586	0	27	603	27	623	0	0	0	0	638	44	0	0	0	682
2012	0	5	343	14	0	0	0	0	2	7	0	353	0	24	329	24	315	0	0	0	0	336	26	0	0	0	362
2013	0	0	311	89	0	0	0	0	0	66	0	334	0	0	388	0	388	0	0	0	0	349	51	0	0	0	400
2014	0	1	249	58	0	0	0	0	0	1	0	307	0	0	283	0	265	0	0	0	0	255	53	0	0	0	308
2015	0	14	319	54	0	0	0	0	0	0	0	387	0	0	381	0	323	0	0	0	0	352	35	0	0	0	387
2016	0	7	403	69	13	0	0	0	0	0	0	492	0	0	459	0	453	0	0	0	0	461	31	0	0	0	492
2017	0	7	456	55	0	0	0	0	0	0	0	518	0	40	445	40	460	0	0	0	1	470	47	0	0	0	518
Total	5684	16246	27377	23683	11732	2498	513	118	18390	12056	7441	49202	762	14115	66385	14073	64815	108	507	10302	22477	48328	5125	595	87	322	87851

Table 3. The number of available measured size data for bluefin tuna caught by the Japanese longline fishery. Year is fishing year (2017 means August 2016 to July 2017).

Fishing Year	West Atlantic	Norhteast Atlantic
2009	3869	19288
2010	1525	16217
2011	4017	9509
2012	1770	7679
2013	1937	6887
2014	1373	7038
2015	1354	6331
2016	1474	7860
2017	1731	8391

Table 4. Categories in each main effect in the standardized CPUE for the West and Northeast Atlantic.

Main effect / Area	West Atlantic	Northeast Atlantic
Stock	West	East
Model	Delta-lognormal	Delta-lognormal
Fishing Year (Year)	1976-2017	1990-2017
Month	Oct, Nov, Dec, Jan, Feb	Aug-Oct, Nov, Dec, Jan-Mar
Area (Figure 4)	5 areas	4 areas
Material of main line (Main)	Nylon, others (since 1994)	Nylon, others (since 1994)
Material of branch line (Bran)	Nylon, others (since 1994)	Nylon, others (since 1994)
Hooks between floats (NHBF)	5– 13 (individual)	4 - 7, 8 - 12 hooks
SST	(0,7], (7,8], (8,9], (9,10], (10,11], (11,12], (12,13], (13,14], (14,15], (15,16], (16,17], (17,18], (18,30]	(0,7], (7,8], (8,9], (9,10], (10,11], (11,12], (12,13], (13,14], (14,15], (15,16], (16,17], (17,18], (18,30]
Area*Month	Random effect	Random effect

Table 5. Model selections for GLMM analysis for positive catch ratio (1st step) and CPUE of positive catch (2nd step) for the (a)West and (b)Northeast Atlantic. Year is fishing year (2017 means August 2016 to July 2017).

(a) West Atlantic

Model (1st step)					AIC
Year+Month+Area	+NHBF	+Main	+Bran	+SST	32739.8
Year+Month+Area	+NHBF	+Main	+Bran		**8837.1**
Year+Month+Area	+NHBF	+Main		+SST	31550.8
Year+Month+Area	+NHBF		+Bran	+SST	32132.3
Year+Month+Area		+Main	+Bran	+SST	16680.8
Year+Month+Area	+NHBF	+Main			8227.6
Year+Month+Area	+NHBF		+Bran		8509.8
Year+Month+Area		+Main	+Bran		**3382.0**
Year+Month+Area		+Main			**2928.9**
Year+Month+Area			+Bran		3083.9
Year+Month+Area					NA

Model (2nd step)					AIC
Year+Month+Area	+NHBF	+Main	+Bran	+SST	91205.3
Year+Month+Area	+NHBF	+Main	+Bran		91823.4
Year+Month+Area	+NHBF	+Main		+SST	**91200.6**
Year+Month+Area	+NHBF		+Bran	+SST	91226.9
Year+Month+Area		+Main	+Bran	+SST	91312.8

(b) Northeast Atlantic

Model (1st step)					AIC
Year+Month+Area	+NHBF	+Main	+Bran	+SST	9332.6
Year+Month+Area	+NHBF	+Main	+Bran		**2711.8**
Year+Month+Area	+NHBF	+Main		+SST	7420.0
Year+Month+Area	+NHBF		+Bran	+SST	7723.9
Year+Month+Area		+Main	+Bran	+SST	6848.0
Year+Month+Area	+NHBF	+Main			1938.5
Year+Month+Area	+NHBF		+Bran		1969.4
Year+Month+Area		+Main	+Bran		**1817.6**
Year+Month+Area		+Main			1263.7
Year+Month+Area			+Bran		**1249.2**
Year+Month+Area					**748.6**

Model (2nd step)					AIC
Year+Month+Area	+NHBF	+Main	+Bran	+SST	79573.6
Year+Month+Area	+NHBF	+Main	+Bran		79634.0
Year+Month+Area	+NHBF	+Main		+SST	**79568.0**
Year+Month+Area	+NHBF		+Bran	+SST	79592.6
Year+Month+Area		+Main	+Bran	+SST	79574.5

Table 6. Statistical results from GLMM analysis for positive catch ratio (1st step) and CPUE of positive catch (2nd step) for the updated standardized CPUEs to 2017FY for the (a)West and (b)Northeast Atlantic in the final model.

(a) West Atlantic

Type 3 Tests of Fixed Effects for proportion of positive catch (1st step)

Effect	Num DF	Den DF	Chi-Square	F Value	Pr > ChiSq	Pr > F
Year	40	653	195.86	4.9	<.0001	<.0001
Month	4	653	456.27	114.07	<.0001	<.0001
Area	4	653	161.28	40.32	<.0001	<.0001
Main	1	72	1.28	1.28	0.2585	0.2622

Type 3 Tests of Fixed Effects for logCPUE with positive catch (2nd step)

Effect	Num DF	Den DF	F Value	Pr > F
Year	41	512	2.98	<.0001
Month	4	512	97.57	<.0001
Area	4	512	6.19	<.0001
NHBF	8	32000	17.83	<.0001
Main	1	32000	33.35	<.0001
SST	12	32000	57.6	<.0001

(b) Notheast Atlantic

Type 3 Tests of Fixed Effects for proportion of positive catch (1st step)

Effect	Num DF	Den DF	Chi-Square	F Value	Pr > ChiSq	Pr > F
Year	22	210	192.1	8.73	<.0001	<.0001
Month	3	210	133.51	44.5	<.0001	<.0001
Area	3	210	23.24	7.75	<.0001	<.0001

Type 3 Tests of Fixed Effects for logCPUE with positive catch (2nd step)

Effect	Num DF	Den DF	F Value	Pr > F
Year	27	204	15.11	<.0001
Month	3	204	32.02	<.0001
Area	3	204	4.26	0.0061
NHBF	1	33000	7.78	0.0053
Main	1	33000	41.77	<.0001
SST	10	33000	11.68	<.0001

Table 7. Nominal CPUE, number of sets, and abundance index statistics for the updated standardized CPUE to 2017FY for the West and Northeast Atlantic. Year is fishing year (2017 means August 2016 to July 2017).

(a) West Atlantic (1976-2017)

Year	Sets	Nominal CPUE	Std. CPUE	Scaled Std. CPUE	Lower 95% CI	Upper 95% CI	CV
1976	1286	2.815	0.763	0.188	0.091	0.389	0.376
1977	2375	4.833	1.877	0.463	0.300	0.714	0.219
1978	1840	3.336	1.042	0.257	0.149	0.444	0.278
1979	2954	1.068	0.842	0.208	0.131	0.329	0.233
1980	3098	1.886	1.542	0.380	0.267	0.542	0.179
1981	5469	2.406	1.822	0.449	0.341	0.592	0.138
1982	5157	0.517	0.817	0.202	0.130	0.313	0.223
1983	3273	0.869	0.447	0.110	0.061	0.199	0.301
1984	2351	1.511	0.964	0.238	0.156	0.363	0.214
1985	2883	2.612	0.869	0.214	0.133	0.346	0.242
1986	2353	0.328	0.051	0.013	0.003	0.054	0.841
1987	3251	1.475	0.628	0.155	0.090	0.266	0.275
1988	3526	1.666	0.850	0.210	0.135	0.327	0.224
1989	3140	0.958	0.697	0.172	0.105	0.283	0.253
1990	3096	0.869	0.552	0.136	0.078	0.237	0.283
1991	2002	0.815	0.505	0.124	0.067	0.233	0.321
1992	1652	1.543	0.912	0.225	0.139	0.363	0.243
1993	1993	1.049	0.864	0.213	0.128	0.356	0.260
1994	1692	1.925	0.924	0.228	0.141	0.369	0.245
1995	954	0.621	0.586	0.145	0.076	0.274	0.328
1996	479	4.150	1.891	0.467	0.305	0.714	0.215
1997	835	2.285	1.021	0.252	0.145	0.438	0.282
1998	1192	1.405	0.481	0.119	0.061	0.229	0.339
1999	1282	1.170	0.476	0.117	0.059	0.235	0.359
2000	1313	1.443	0.602	0.148	0.080	0.274	0.315
2001	1289	0.670	0.533	0.131	0.063	0.276	0.385
2002	2258	0.549	0.557	0.137	0.073	0.257	0.321
2003	800	0.835	0.362	0.089	0.036	0.222	0.482
2004	836	2.024	0.374	0.092	0.038	0.222	0.461
2005	1784	1.204	0.575	0.142	0.085	0.237	0.260
2006	1079	1.575	1.078	0.266	0.161	0.440	0.256
2007	370	5.224	1.401	0.346	0.208	0.574	0.258
2008	238	1.479	0.714	0.176	0.082	0.378	0.396
2009	54	2.200	1.649	0.407	0.204	0.811	0.356
2010	230	0.233	0.628	0.155	0.077	0.312	0.361
2011	372	4.004	1.897	0.468	0.279	0.785	0.263
2012	260	1.862	3.337	0.823	0.534	1.268	0.218
2013	352	1.780	2.235	0.551	0.345	0.882	0.238
2014	175	1.300	2.377	0.586	0.356	0.966	0.254
2015	379	1.148	1.490	0.368	0.218	0.619	0.265
2016	211	2.512	3.202	0.790	0.448	1.391	0.289
2017	71	1.901	4.054	1.000	0.594	1.683	0.265

(b) Notheast Atlantic (1990-2017)

Year	Sets	Nominal CPUE	Std. CPUE	Scaled Std. CPUE	Lower 95% CI	Upper 95% CI	CV
1990	313	0.831	0.415	0.041	0.022	0.078	0.323
1991	1261	0.891	0.521	0.052	0.030	0.090	0.278
1992	2198	1.076	0.885	0.088	0.063	0.124	0.168
1993	2086	0.976	0.830	0.083	0.063	0.109	0.139
1994	1300	1.491	1.008	0.101	0.074	0.138	0.157
1995	810	1.758	1.049	0.105	0.079	0.138	0.139
1996	1520	2.564	2.604	0.260	0.201	0.337	0.129
1997	2694	1.315	1.648	0.165	0.128	0.213	0.129
1998	3137	0.976	0.902	0.090	0.066	0.124	0.159
1999	2759	0.991	1.172	0.117	0.087	0.158	0.151
2000	3488	1.018	1.109	0.111	0.088	0.140	0.117
2001	2766	1.371	1.426	0.143	0.112	0.182	0.123
2002	2043	0.866	1.082	0.108	0.084	0.140	0.130
2003	1781	1.158	1.182	0.118	0.089	0.157	0.144
2004	3062	0.981	1.005	0.100	0.079	0.127	0.119
2005	3296	0.765	0.737	0.074	0.058	0.093	0.119
2006	2626	0.933	0.854	0.085	0.068	0.108	0.116
2007	1580	0.968	0.872	0.087	0.069	0.110	0.118
2008	1368	1.308	1.055	0.105	0.083	0.134	0.119
2009	1526	2.031	1.528	0.153	0.121	0.192	0.115
2010	741	3.505	2.300	0.230	0.176	0.301	0.135
2011	341	4.761	4.351	0.435	0.313	0.605	0.166
2012	181	7.512	8.008	0.801	0.506	1.266	0.232
2013	200	6.211	6.637	0.664	0.464	0.948	0.180
2014	154	9.245	10.001	1.000	0.637	1.571	0.229
2015	193	6.610	6.059	0.606	0.385	0.952	0.229
2016	246	5.871	5.560	0.556	0.372	0.832	0.203
2017	259	5.904	7.420	0.742	0.473	1.163	0.228

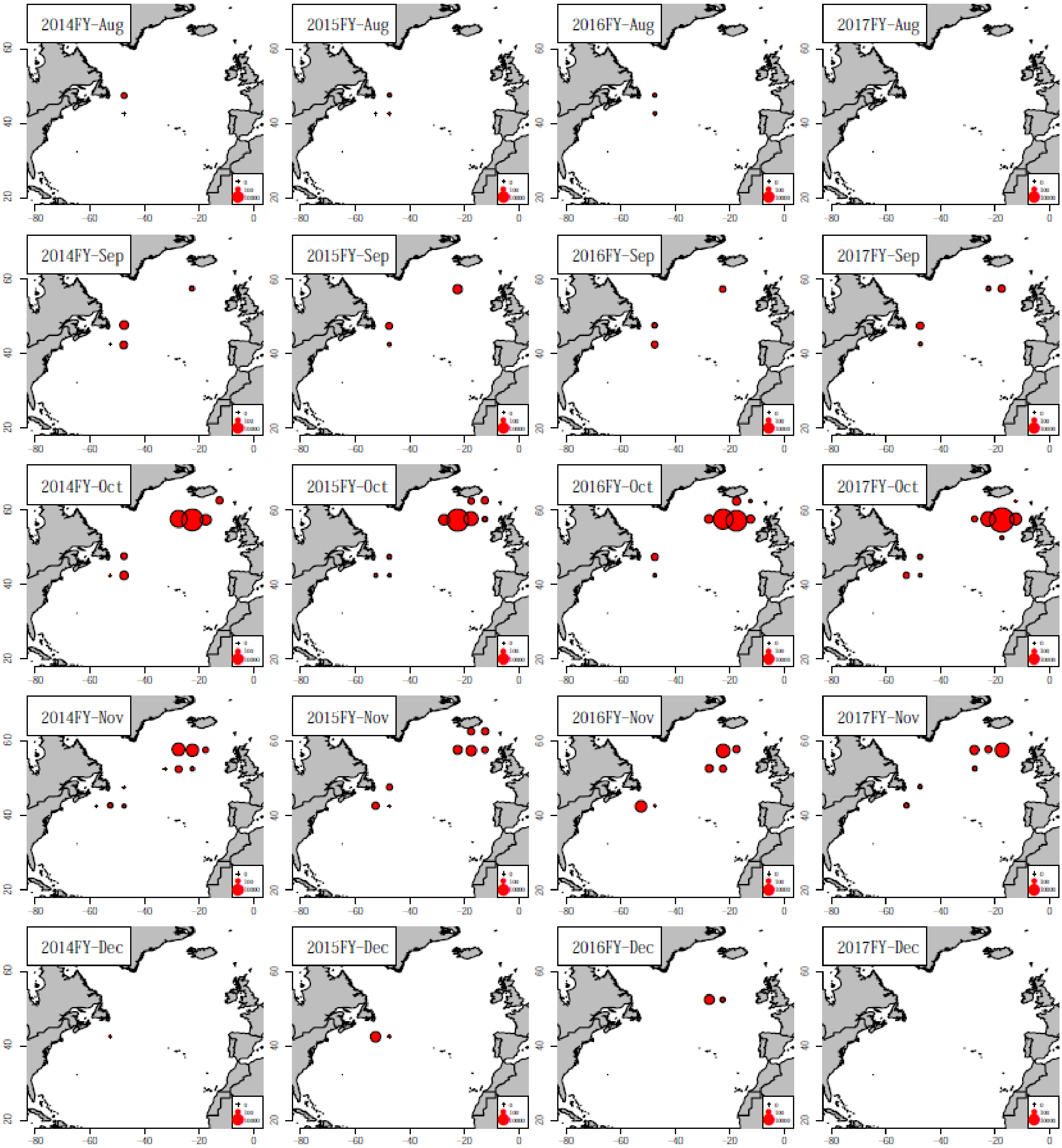


Figure 1. Monthly distributions of accumulative bluefin catch in number by Japanese longliners by 5x5 degree area in the main season (August-December: top to bottom) in the period between 2014 and 2017 FYs (left to right). FY is fishing year (2017 means August 2016 to July 2017).

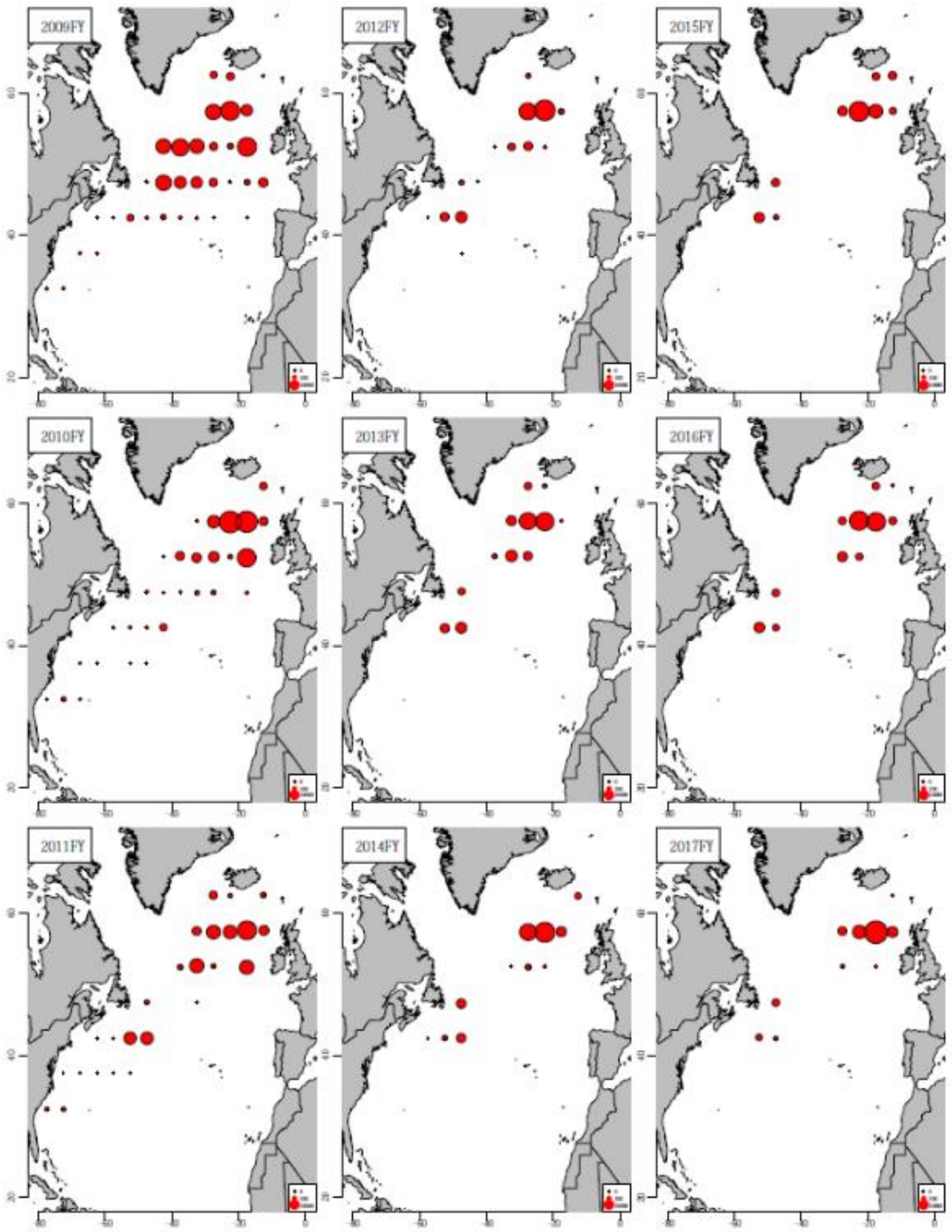


Figure 2. Yearly distributions of accumulative bluefin catch in number by Japanese longliners by 5x5 degree area in the period between 2009 and 2017 FYs. FY is fishing year (2017 means August 2016 to July 2017).

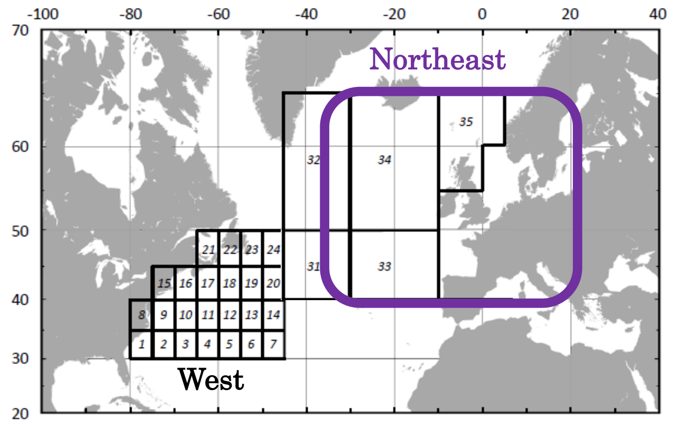


Figure 3. Original area stratification considered in the CPUE standardization for the West and Northeast Atlantic. Numbers from 1 through 24 and from 31 through 35 denote for the West and the Northeast Atlantic, respectively. Numbers indicate original area stratification used in **Tables 1-2**.

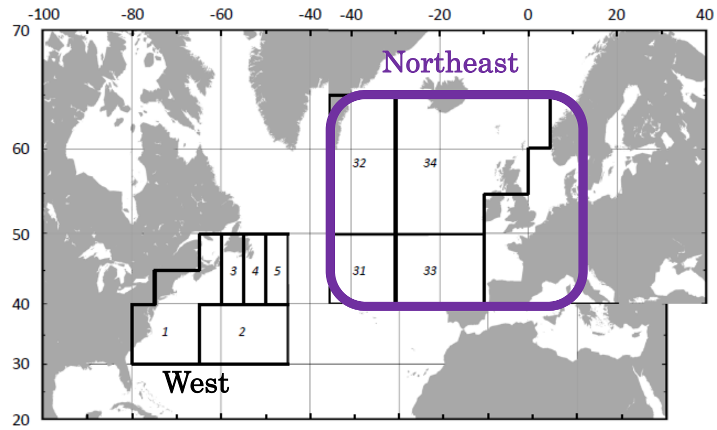


Figure 4. Combined areas used in the CPUE standardization for the West and the Northeast Atlantic. Numbers from 1 through 5 and from 31 through 34 denote for the West and the Northeast Atlantic, respectively. For the split CPUE in the Northeast Atlantic, the combined areas (31-32, and 33-34) were used for the analysis.

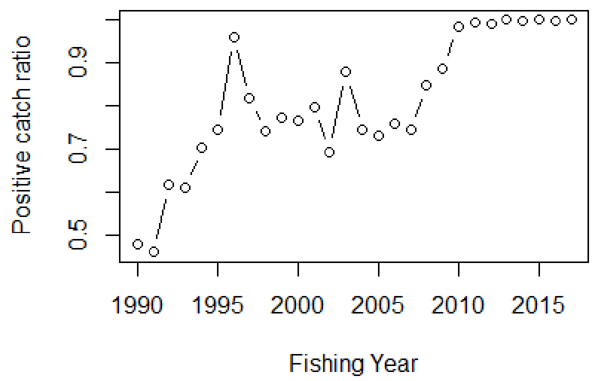
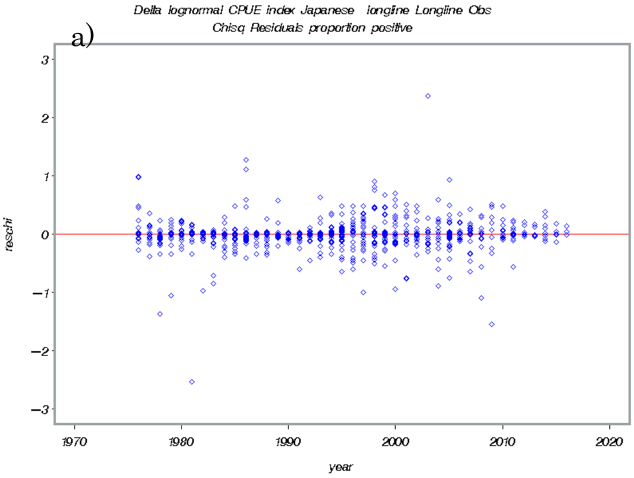


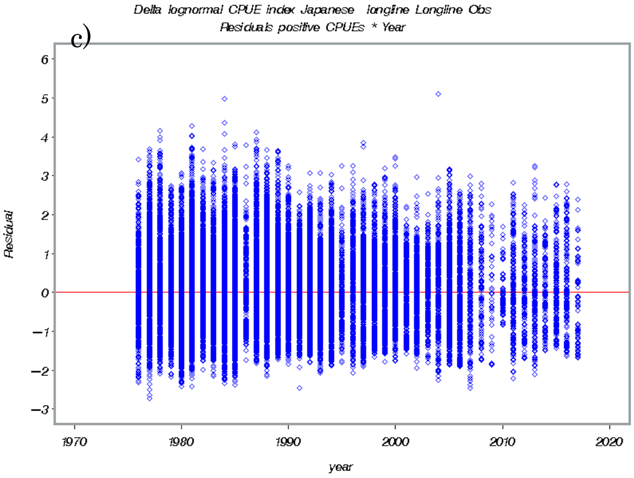
Figure 5. The positive catch ratio in the Northeast Atlantic in the entire analyzed period.

a)


Delta lognormal CPUE index Japanese longline Longline Obs
Chisq Residuals proportion positive
reschi
year
1970
1980
1990
2000
2010
2020
3
2
1
0
−1
−2
−3

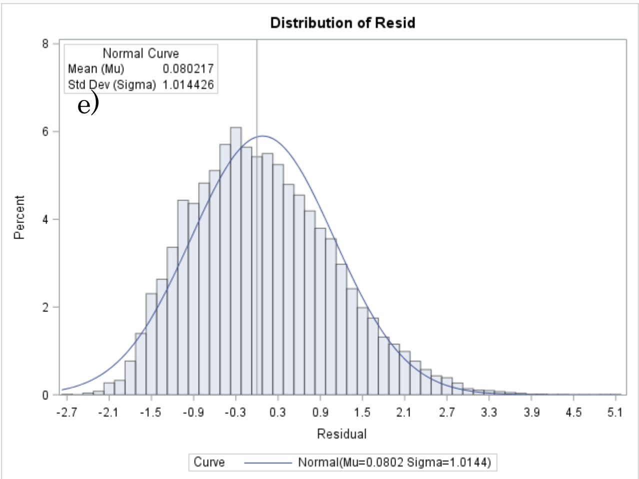
b)

c)


Delta lognormal CPUE index Japanese longline Longline Obs
Residuals positive CPUEs * Year
Residual
year
1970
1980
1990
2000
2010
2020
6
5
4
3
2
1
0
−1
−2
−3

d)

e)


Distribution of Resid
Normal Curve
Mean (Mu) 0.080217
Std Dev (Sigma) 1.014426
Percent
Residual
-2.7
-2.1
-1.5
-0.9
-0.3
0.3
0.9
1.5
2.1
2.7
3.3
3.9
4.5
5.1
8
6
4
2
0
Curve
Normal(Mu=0.0802 Sigma=1.0144)

f)

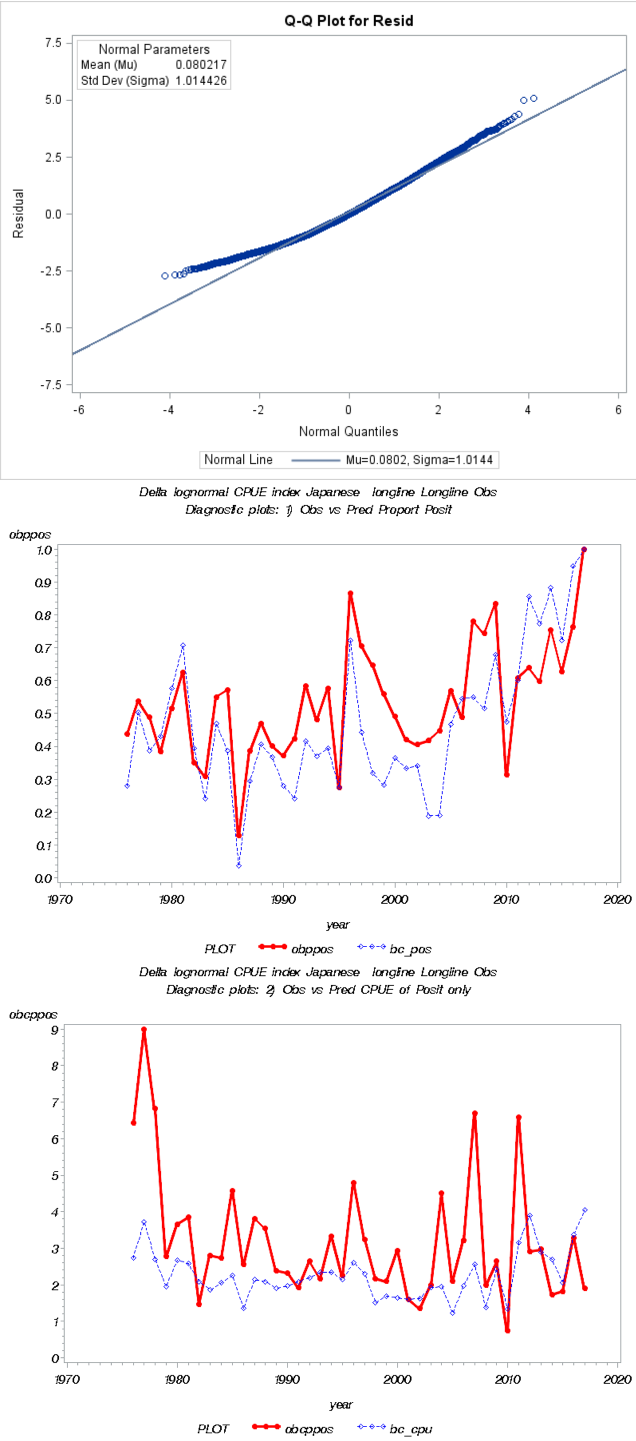
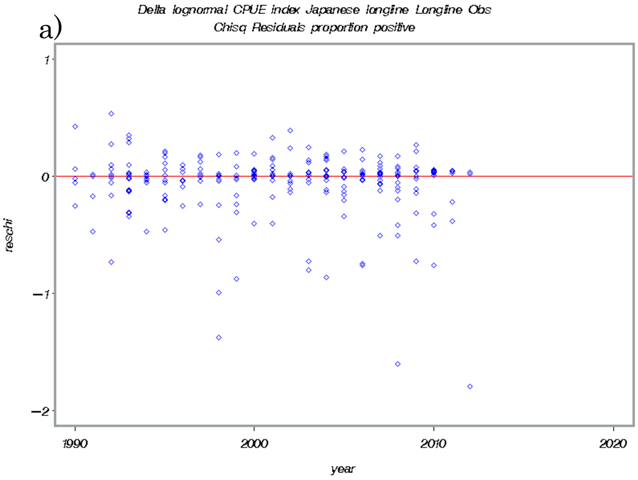


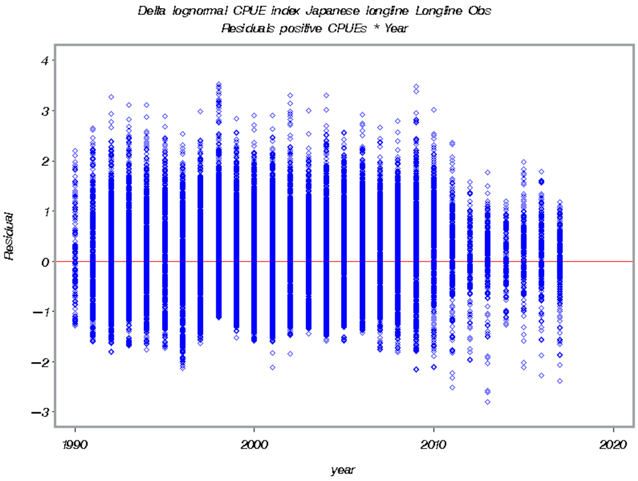
Figure 6. Model diagnostics of the CPUE in the period between 1976 and 2017FY for the West Atlantic: residual distributions in the (a) 1st and (b) 2nd steps of CPUE standardization, (c) distribution and (d) qqplot of the residuals for the positive CPUE, (e) observed (red line) and predicted (blue line) proportion of positive catch observation, and (f) observed (red line) and predicted (blue line) CPUE of positive catch set using delta-lognormal model.

a)


Delta lognormal CPUE index Japanese longline Longline Obs
Chisq Residuals proportion positive
reschi
year

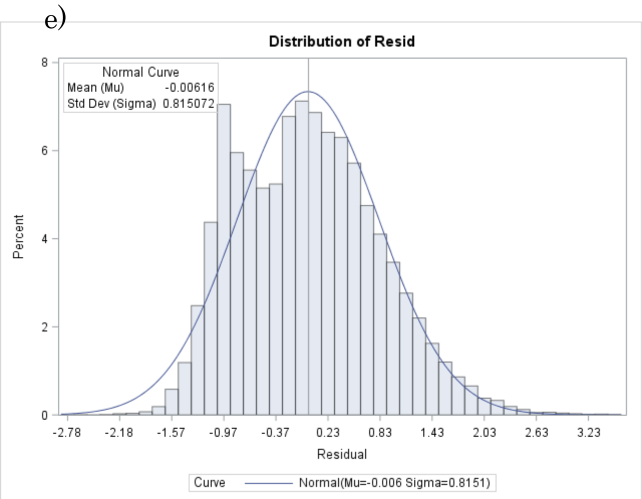
b)

c)


Delta lognormal CPUE index Japanese longline Longline Obs
Residuals positive CPUEs * Year
Residual
year

d)

e)


Distribution of Resid
Normal Curve
Mean (Mu) -0.00616
Std Dev (Sigma) 0.815072
Percent
Residual
Curve Normal(Mu=-0.006 Sigma=0.8151)

f)

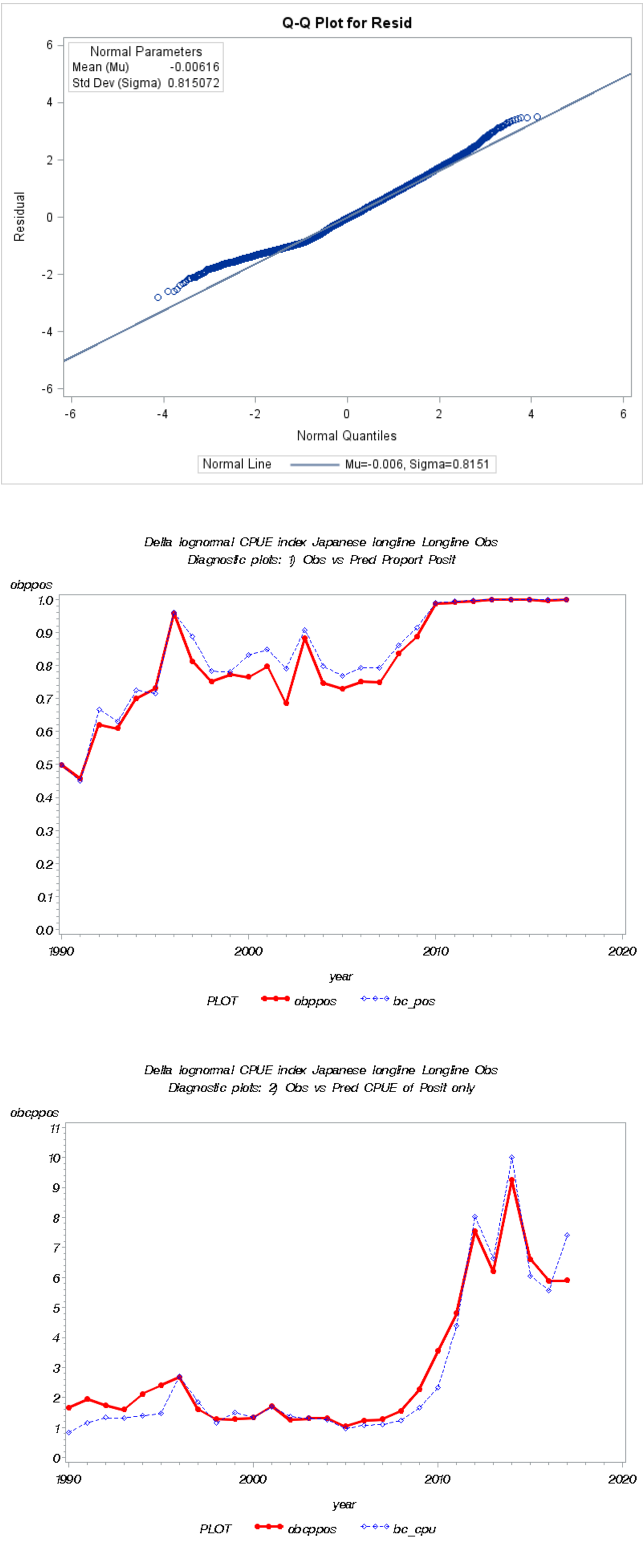
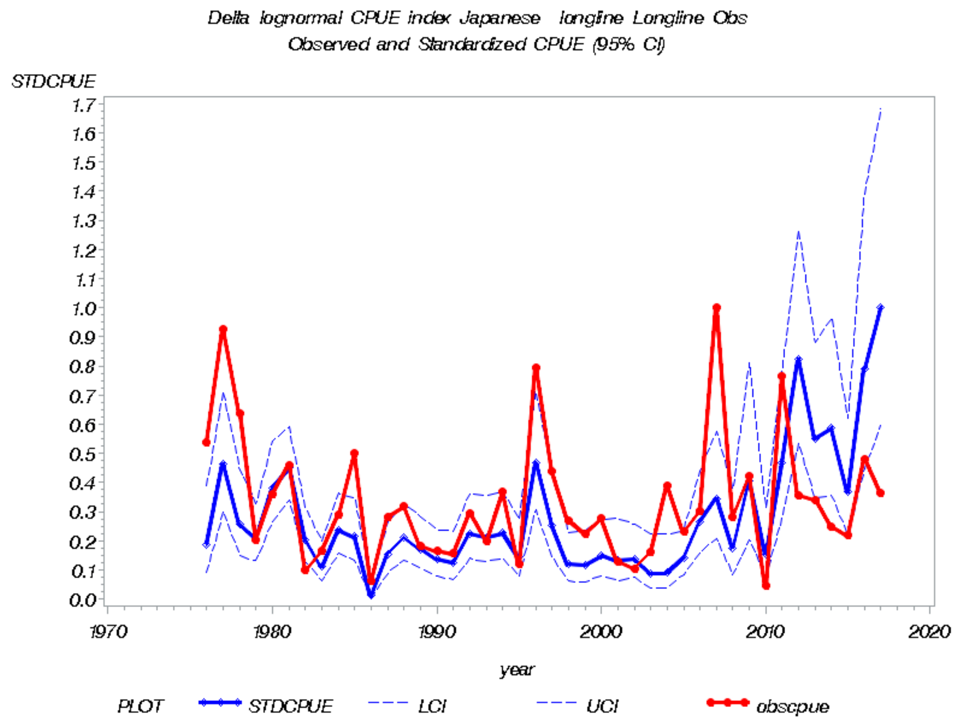


Figure 7. Model diagnostics of the CPUE in the period between 1990 and 2017FY for the Northeast Atlantic: residual distributions in the (a) 1st and (b) 2nd steps of CPUE standardization, (c) distribution and (d) qqplot of the residuals for the positive CPUE, (e) observed (red line) and predicted (blue line) proportion of positive catch observation, and (f) observed (red line) and predicted (blue line) CPUE of positive catch set using delta-lognormal model.

(a) West Atlantic



(b) Northeast Atlantic

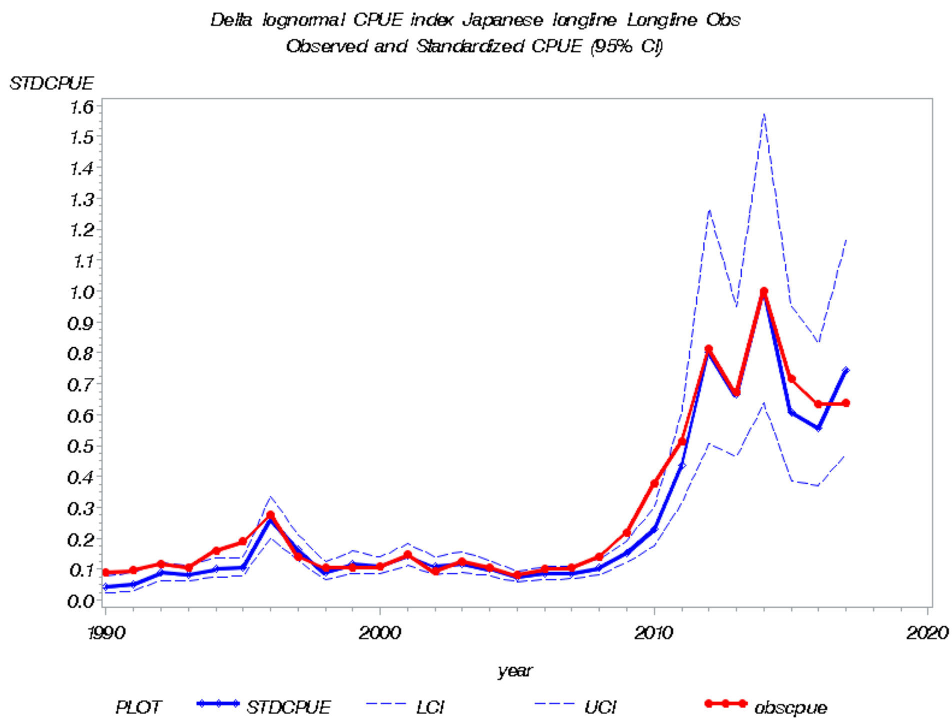
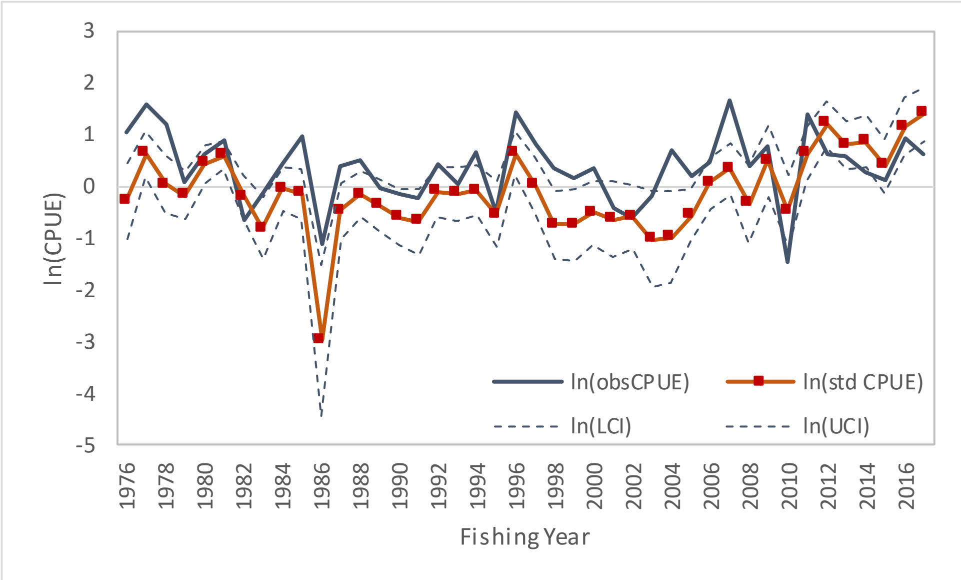


Figure 8. Standardized CPUE (blue line) with 95% confidence intervals and nominal CPUE (red line) for (a) the West Atlantic and (b) the Northeast Atlantic. Year is fishing year (2017 means August 2016 to July 2017).

(a) West Atlantic



(b) Northeast Atlantic

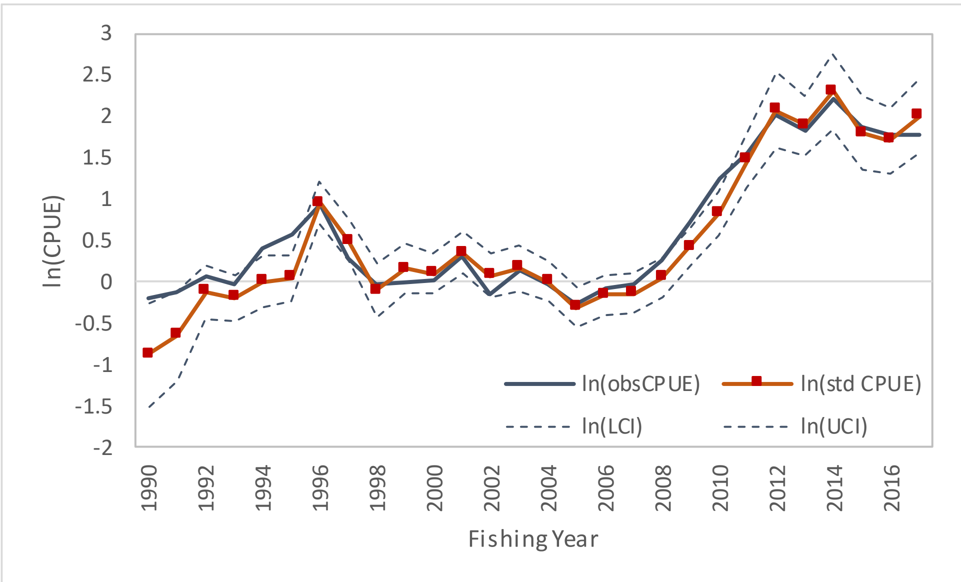


Figure 9. Standardized CPUE with 95% confidence intervals (blue lines) and nominal CPUE (red line) in logarithmic scale for (a) the West Atlantic and (b) the Northeast Atlantic. Year is fishing year (2017 means August 2016 to July 2017).

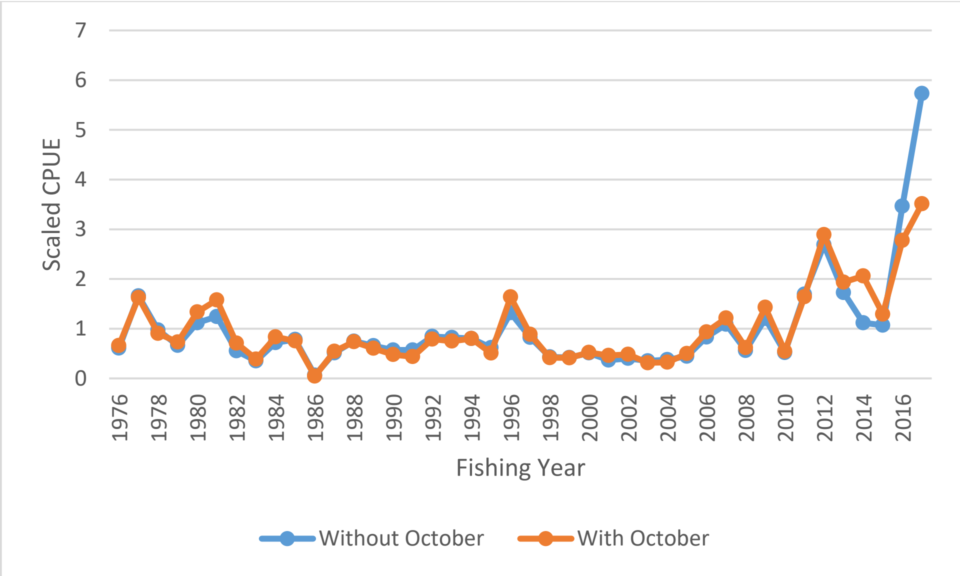


Figure 10. Standardized CPUE in the West Atlantic with or without the data in October (orange or blue lines). Year is fishing year (2017 means August 2016 to July 2017).

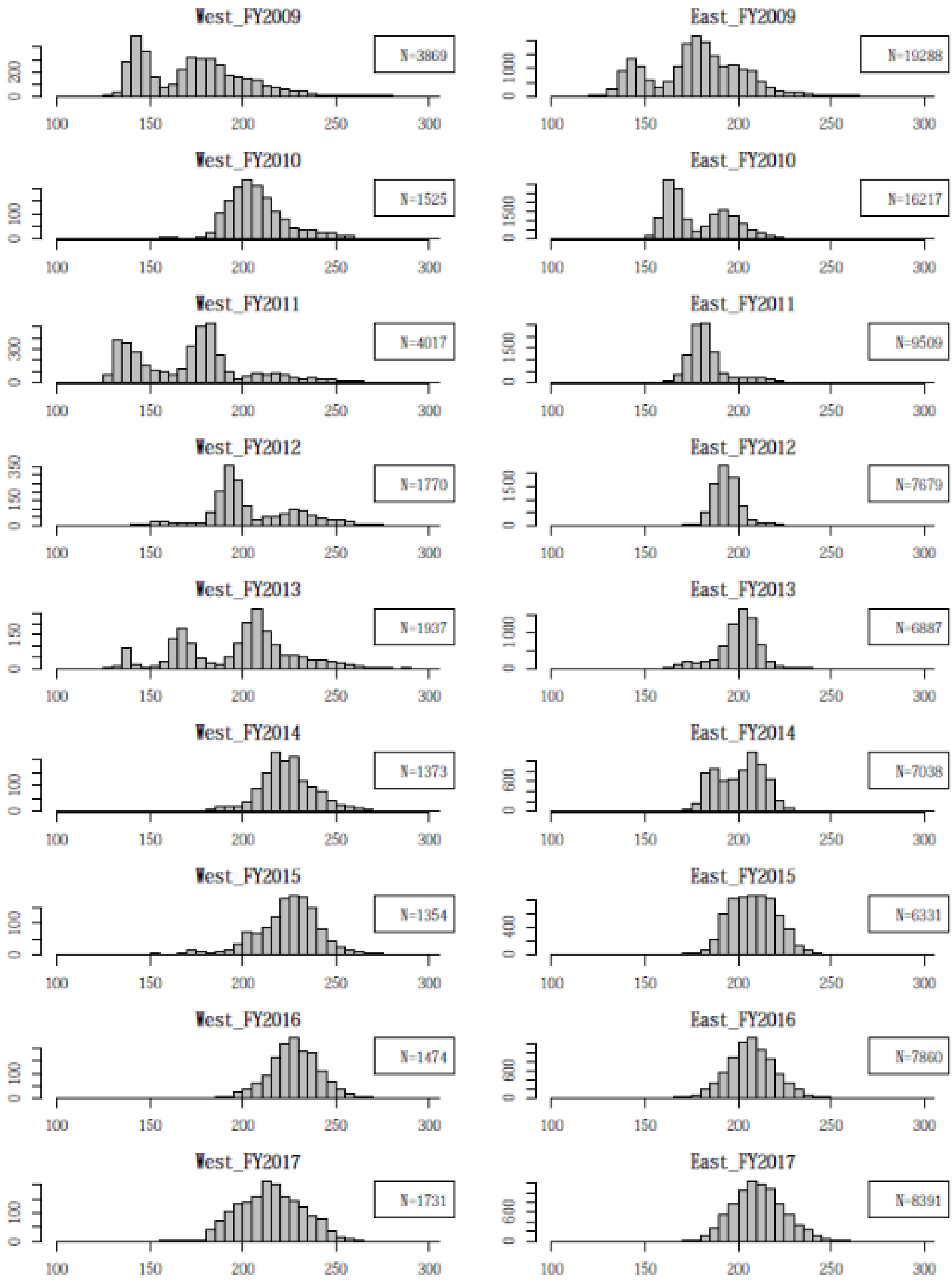


Figure 11. Converted fork length frequencies using the length-weight conversion factors from Japanese scientific observer data from 2009 to 2017FY measured by on board size measurement program in the west Atlantic (left panel) and the Northeast Atlantic (right panel). FY is fishing year (2017 means August 2016 to July 2017).

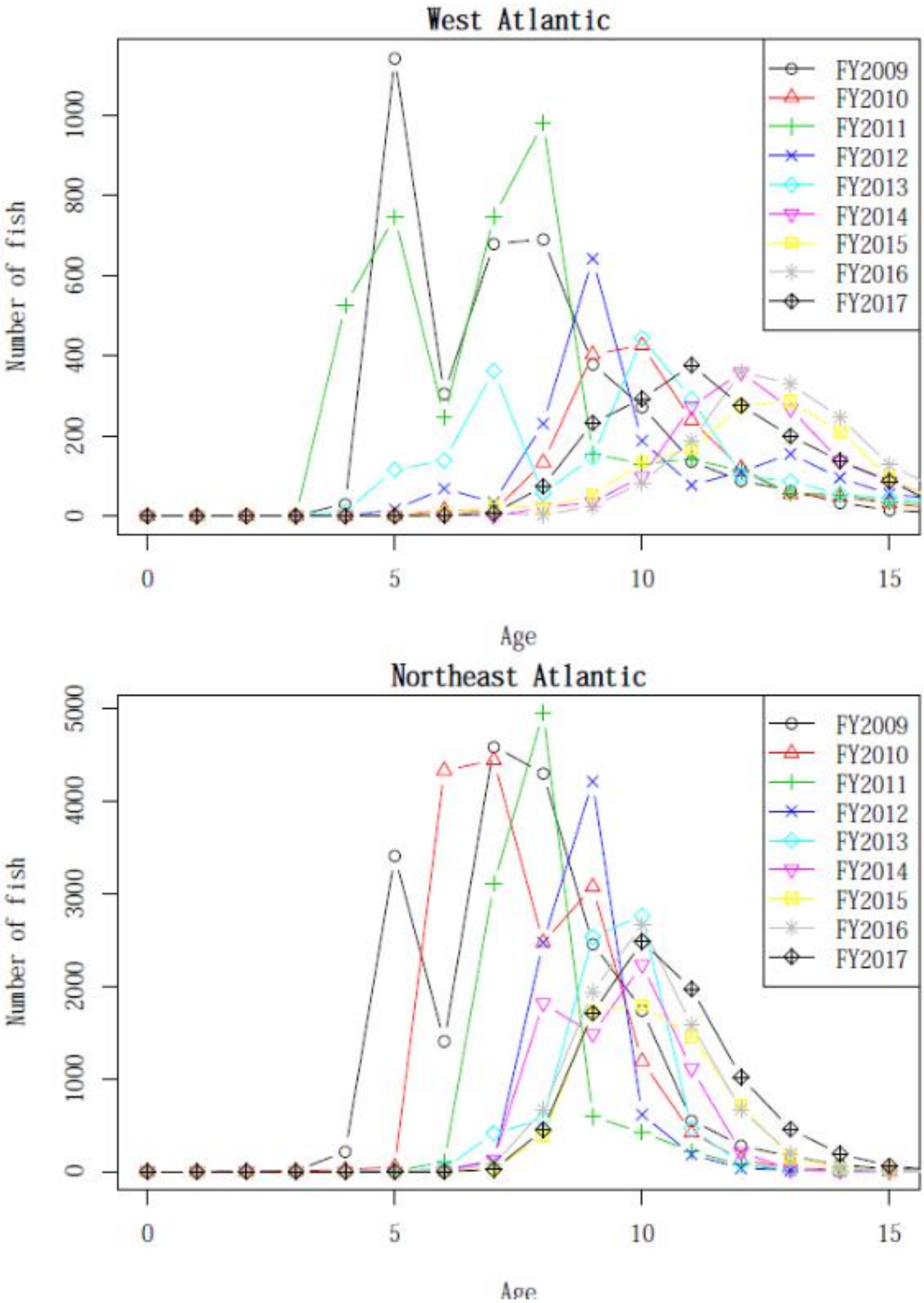


Figure 12. Catch at age was estimated for 2009 through 2017FYs from the converted size data in the West (top panel) and Northeast Atlantic (bottom panel), applying slicing procedures to the size frequencies of bluefin caught by the Japanese longliners. FY is fishing year (2017 means August 2016 to July 2017).