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Updated Japanese longline CPUE for bigeye tuna in the Indian Ocean standardized by GLM

Keisuke SATOH and Hiroaki OKAMOTO

National Research Institute of Far Seas Fisheries
5 chome 7-1, Orido, Shimizu-Ku, Shizuoka-City, 424-8633, Japan

Abstract

Standardized Japanese longline CPUE for bigeye tuna was updated from 1960 up to 2011 by using GLM (CPUE log normal error structured model). Method of standardization was as same as that used for bigeye assessment in 2011. NHF (number of hooks between float) and material of main line were applied to standardize the change in catchability of longline gear. The standardized CPUEs of three regions were almost identical with the indices of the last assessment (2011). In the tropical Indian Ocean, CPUE slightly decreased from around 9.5 (real scale) in 1960 to 6.5 in 1976. It suddenly jumped up to around 12 in 1977 and 1978 and then it was declined and stable to around 1990 with some fluctuation, after that it had continuously decreased to 3.2 in 2002. It was 4.8 in 2011, which is larger than those of the last decade (3.2 – 4.7). The standardized CPUE in the south region also increased (8.3) in 1977 and then showed slightly decreasing trend. It was 2.7 in 2011 which is around average of the last decade (1.3 - 3.2). As a result, CPUE in whole Indian Ocean, which had been in the same level around 5 to 7 until 1976 and suddenly increased around 10 in 1977 and 1978 and after that showed slightly decreasing trend. It was 3.8 in 2011, which is equal to upper value of the range of the last decade (2.5 - 3.8).

1. Introduction

Standardized Japanese longline CPUE for bigeye tuna was updated from 1960 to 2011 by GLM (CPUE log normal error structured model) in order to provide abundance index in IOTC WPTT meeting in 2012 to see whether the catch rates are similar to previous years. Method of standardization was the same as that used for bigeye assessment in 2011 (Okamoto, 2011).

2. Materials and methods

Area definition:

Area definition used in this study (**Fig. 1**) is the same as that used in the IOTC bigeye assessment in 2006 (Okamoto and Shono, 2006) which consists of seven areas. Main fishing ground of Japanese longline fishery for bigeye was divided into seven areas and CPUE standardization was done for three cases of area combinations, tropical (areas 1-5), south (areas 6 & 7) and whole (areas 1-7) Indian Ocean. Area 67 in the south area was not used in this study.

Environmental factors:

As environmental factors, which are available for the analyzed period from 1960 to 2011, SST (sea surface temperature) was applied. The original SST data, whose resolution is 1-degree latitude and 1-degree longitude by month from 1946 to 2011, was downloaded from NEAR-GOOS Regional Real Time Data Base of Japan Meteorological Agency (JMA) http://goos.kishou.go.jp/rrtdb/database.html. It is necessary to get password to access the data retrieving system. The original data was recompiled into 5-degree latitude and 5-latitude longitude by month from 1960 to 2011 using the procedures described in Okamoto et al. (2001), and used in the analyses.

Catch and effort data used:

The Japanese longline catch (in number) and effort statistics from 1960 up to 2011 were used. The catch and effort data set from aggregated by month, 5-degree square, NHF (the number of hooks between floats), and main line material, was used for the analysis. Data in strata in which the number of hooks was less than 5000 were not used for analyses. As the NHF information does not available for the period from 1960 to 1974, NHF was regarded to be 5 in this period. Main line material was categorized in to two, 1 = Nylon and 2 = other, which was not available before 1993. The main line material was assumed as ‘other’ from 1975 to 1993 except as NHF was over 18 from 1990 to 1993, where it was assumed as ‘Nylon’.

CPUEs based on the number of catch was used; The number of caught fish / the number of hooks * 1000. The model used for GLM analyses (CPUE log normal error structured model) was as follows;

Log [CPUE +const] = μ + year + month + area + NHFC + SST + ML + year*area + month*area + area*NHFC + area*SST + NHFC*ML + error

where Log: natural logarithm, CPUE: catch in number of bigeye per 1000 hooks, const: 10% of overall mean of CPUE, μ: overall mean (i.e. intercept), year: effect of year, month: effect of fishing season (month), area: effect of sub-area, NHFC: effect of gear type (class of the number of hooks between floats. The number of hooks between float (NHF) was divided into 6 classes (NHFC 1: 5-7, NHFC 2: 8-10, NHFC 3: 11-13, NHFC 4: 14-16, NHFC 5: 17-19, NHFC 6: 20-21), SST: effect of SST, ML: effect of material of main line, error ~ normal (0, σ^2). Variable selection was conducted by a backwards stepwise F-test with a criterion of P = 0.05.

Effect of year was obtained by the method used in Shono and Ogura (1999) that uses lsmean of Year-Area interaction as the following equation.

$CPUE_i = \Sigma W_j * (\exp(\text{lsmean}(\text{year } i*\text{area}_j)) - \text{constant})$

where $CPUE_i$ = CPUE in year i, W_j = area rate of Area j , ($\Sigma W_j = 1$), lsmean (year*area_{ij}) = least square mean of year-area interaction in year i and area j, constant = 10% of overall mean of CPUE. Time period of standardization was 1960-2011 for both of annual CPUE.

3. Results and discussion

CPUE standardizations by GLM:

The bigeye tuna CPUE (catch in number per 1000 hooks) was standardized by GLM (CPUE log normal error structured model) for each of three area categories, tropical (areas 1 – 5), south (areas 6 & 7) and whole Indian Ocean (areas 1 – 7) for three periods 1960-2011.

Trends of CPUE in each region (tropical, south and whole of the Indian Ocean) were shown in **Fig. 2** overlaying nominal CPUE and standardized CPUE of the last assessment (2011). The new standardized CPUEs of three regions were almost identical with the indices of the last assessment (2011). In the tropical Indian Ocean, CPUE slightly decreased from around 9.5 (real scale) in 1960 to 6.5 in 1976. It suddenly jumped up to around 12 in 1977 and 1978 and then it was declined and stable to around 1990 with some fluctuation, after that it had continuously decreased to 3.2 in 2002. It was 4.8 in 2011, which is larger than those of the last decade (3.2 – 4.7). The standardized CPUE in the south region also increased (8.3) in 1977 and then showed slightly decreasing trend. It was 2.7 in 2011 which is around average of the last decade (1.3 - 3.2). As a result, CPUE in whole Indian Ocean, which had been in the same level around 5 to 7 until 1976 and suddenly increased around 10 in 1977 and 1978 and after that showed slightly decreasing trend. It was 3.8 in 2011, which is equal to upper value of the range of the last decade (2.5 - 3.8). Results of ANOVA and distributions of the standard residual by year in each analysis were shown in **Table 1** and **Fig. 3**, respectively. Distributions of the standard residual did not show remarkable difference from the normal distribution. Annual values of standardized CPUE by region were listed in **Appendix Table 1**.

There was large discrepancy between the nominal and the standardized CPUE in the tropical region from 1977 and 2002, whereas in the same period there was no such difference in the south region (**Fig. 2**). In order to detect the reason of the difference, we investigated regional difference of effect of each factor (SST, month, NHFC and ML) on the CPUE standardization. The stepwise illustration of the factors influencing this divergence was undertaken. The lsmeans (least square mean) of year effect between the final model and modified model, which is excluding each explanatory variable (SST, month, NHFC and ML) from the final model, were compared.

In first, historical changes of target species, gear setting and material of the main line for Japanese longline in the Indian Ocean were investigated. The proportion of species in catch number for each region (**Fig. 5**) indicated historical changes of target species. In the tropical area, bigeye tuna was main target species since 1977, whereas in the south region the main target species was yellowfin tuna. The deep gear setting (NHFC 3) was applied in the tropical region from 1977 to around 1990, on the other hand in the south region the shallow gear setting (NHFC 1) had remained to use in the same period (**Fig. 6**). The extra deep setting (>= NHFC 4) have been put into use in the tropical region after 1990. In the south region the relative shallow setting (NHFC 2) was main gear configuration in the same period, and the deep and the extra deep setting were gradually applied after 1990. Nylon for material of the main line have been used since 1990 in both regions, however the proportion of using for “the other” material of the main line was still high during 1990s in the south region (**Fig. 7**). These properties of target species, gear setting and material of the main line of three periods (1960-1976, 1977-1993 and 1994-2011) were summarized in **Table 2**.

Comparison for year-effect between the final model and the modified model

NHFC

In the tropical region, the modified model (without variable for NHFC; Log [CPUE +const] = μ + year +

month + area + SST + ML + year*area + month*area + area*SST + error) resulted in lower standardized annual CPUE relative to the final model before 1976, and higher standardized CPUE after 1977, which is coincide with the historical changes of NHFC in the region (**Fig. 8**). Assuming lower and higher fishing efficiency for bigeye tuna of the shallow and deep setting, respectively, explains well the historical differences of the modified and the final model. In case of same level of biomass, fishing gear with low efficiency leads to lower nominal CPUE rather than using the fishing gear with high fishing efficiency. Although the application of the extra deep setting in early 1990s showed smaller impact on the fishing efficiency rather than the changes from the shallow setting to the deep setting in 1977, the fishing efficiency with the extra deep setting after 1990 have continued to slightly increase.

In the south region, the modified model consistently showed lower standardized CPUE unlike with the tropical region. The consistency is correlated with the fact that the deep setting did not use in 1977 in the south region. The increasing of fishing efficiency with NHFC after 1995 in the south region was partially because of the increasing of the deep setting.

ML

In the tropical region, the model without ML resulted in higher standardized CPUE from 1977 to 1990. It is not clear the reason for the higher CPUE because there was only one class (“other than Nylon”) in the period (**Fig. 9**). However the deep setting was introduced in the period, the higher CPUE may relate to the change of gear configuration. The material of main line used for the shallow setting might be suitable for the deep setting without any alternation. After 1990 the standardized CPUE of the modified model showed slightly low, which may result from the lower fishing efficiency of the extra deep setting with Nylon of the mainline for bigeye tuna.

In the south region, the historical changes of difference between the final model and the modified model without ML were similar to those of NHFC in this region. The increasing of fishing efficiency after 1995 in the south region was related to increasing of Nylon mainline for the deep setting.

SST, month

There were no clear historical trends of differences between the modified models (without SST and without month) and the final model in both regions except for large annual changes for the south region (**Fig. 10**). The large changes may reflect with the relatively large changes of environmental conditions.

The main reasons for the discrepancy between the nominal and the standardized CPUE in the tropical region are related to the historical changes of NHFC and ML. The deep setting put into use from 1977 to early 1990s, and the fishing efficiency for bigeye tuna increased, which resulted in increasing nominal CPUE. On the other hand, in the tropical region the shallow setting was mainly used in the period, therefore there is no increasing of the nominal CPUE. From early 1990s to early 2000s the extra deep setting with Nylon mainline had been used in the tropical region, however the impact of the changing on fishing efficiency for bigeye tuna was relatively small. Simultaneously the proportion of bigeye tuna became gradually small, Japanese fisherman had targeted on yellowfin tuna as well as bigeye tuna in this period. Therefore the discrepancy of the nominal and standardized CPUE became small in this period.

4. References

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Okamoto, H., Miyabe, N., and Matsumoto, T. (2001): GLM analyses for standardization of Japanese longline CPUE for bigeye tuna in the Indian Ocean applying environmental factors. IOTC-2001/TTWP/21, p. 38.

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Table 1. ANOVA tables of GLM for bigeye tuna standardized CPUE for Japanese longline. CV, the coefficient of variation, which describes the amount of variation in the population, is 100 times the standard deviation estimate of the dependent variable (CPUE), Root MSE (Mean Square for Error), divided by the Mean.

tropical

RSquare	CV				
0.34	31.35				
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Model	347	5520.83	15.91	48.53	<.0001
year	51	615.02	12.06	36.79	<.0001
month	11	127.07	11.55	35.24	<.0001
area	4	155.51	38.88	118.59	<.0001
nhfc	5	38.57	7.71	23.53	<.0001
sst	1	16.30	16.30	49.72	<.0001
ml	1	1.47	1.47	4.49	0.0341
year*area	201	577.70	2.87	8.77	<.0001
month*area	44	213.44	4.85	14.8	<.0001
area*nhfc	20	60.38	3.02	9.21	<.0001
sst*area	4	143.11	35.78	109.14	<.0001
nhfc*ml	5	56.03	11.21	34.18	<.0001

south

RSquare	CV				
0.36	77.03				
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Model	142	5488.84	38.65	66.21	<.0001
year	51	1023.27	20.06	34.37	<.0001
month	11	688.83	62.62	107.27	<.0001
area	1	44.19	44.19	75.69	<.0001
nhfc	5	55.33	11.07	18.96	<.0001
sst	1	283.21	283.21	485.13	<.0001
ML	1	1.72	1.72	2.95	0.0859
year*area	51	244.13	4.79	8.2	<.0001
month*area	11	71.88	6.53	11.19	<.0001
area*nhfc	5	31.95	6.39	10.95	<.0001
sst*area					
nhfc*ML	5	17.68	3.54	6.06	<.0001

whole

RSquare	CV				
0.44	41.47				
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Model	418	13961.02	33.40	83.13	<.0001
year	51	803.51	15.76	39.21	<.0001
month	11	131.37	11.94	29.73	<.0001
area	5	148.95	29.79	74.15	<.0001
nhfc	5	84.26	16.85	41.94	<.0001
sst	1	1.43	1.43	3.57	0.0589
ML	1	0.94	0.94	2.34	0.1259
year*area	254	1329.78	5.24	13.03	<.0001
month*area	55	728.88	13.25	32.99	<.0001
area*nhfc	25	106.94	4.28	10.65	<.0001
sst*area	5	146.48	29.30	72.92	<.0001
nhfc*ML	5	51.33	10.27	25.55	<.0001

Table 2. Summary of target species (from catch proportion by species in number), gear setting depth (judged by NHFC) and material of main line of Japanese longline in the Indian Ocean.

region	period	target	gear setting	material of main line
tropical	1960-1976	**YFT**>BET>ALB	shallow	others
	1977-1993	**BET**>YFT	deep	others
	1994-2011	**BET**>YFT	extra deep	Nylon
south	1960-1976	**ALB**>YFT	shallow	others
	1977-1993	**YFT**>BET	shallow	others
	1994-2011	**YFT**>BET, ALB	deep	Nylon

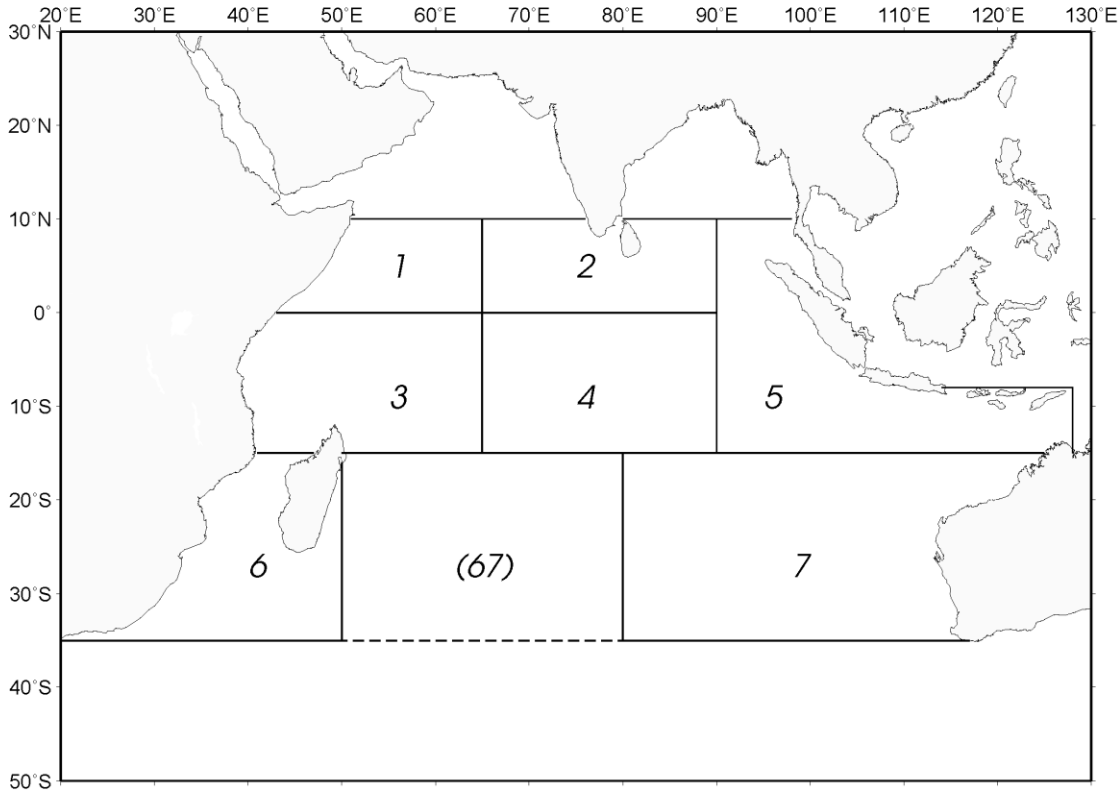


Fig. 1 Definition of sub-areas used in this study. The tropical, south and whole Indian Ocean regions in this paper consist of areas 1-5, areas 6-7 and areas1-7, respectively. Area 67 was not used in this study.

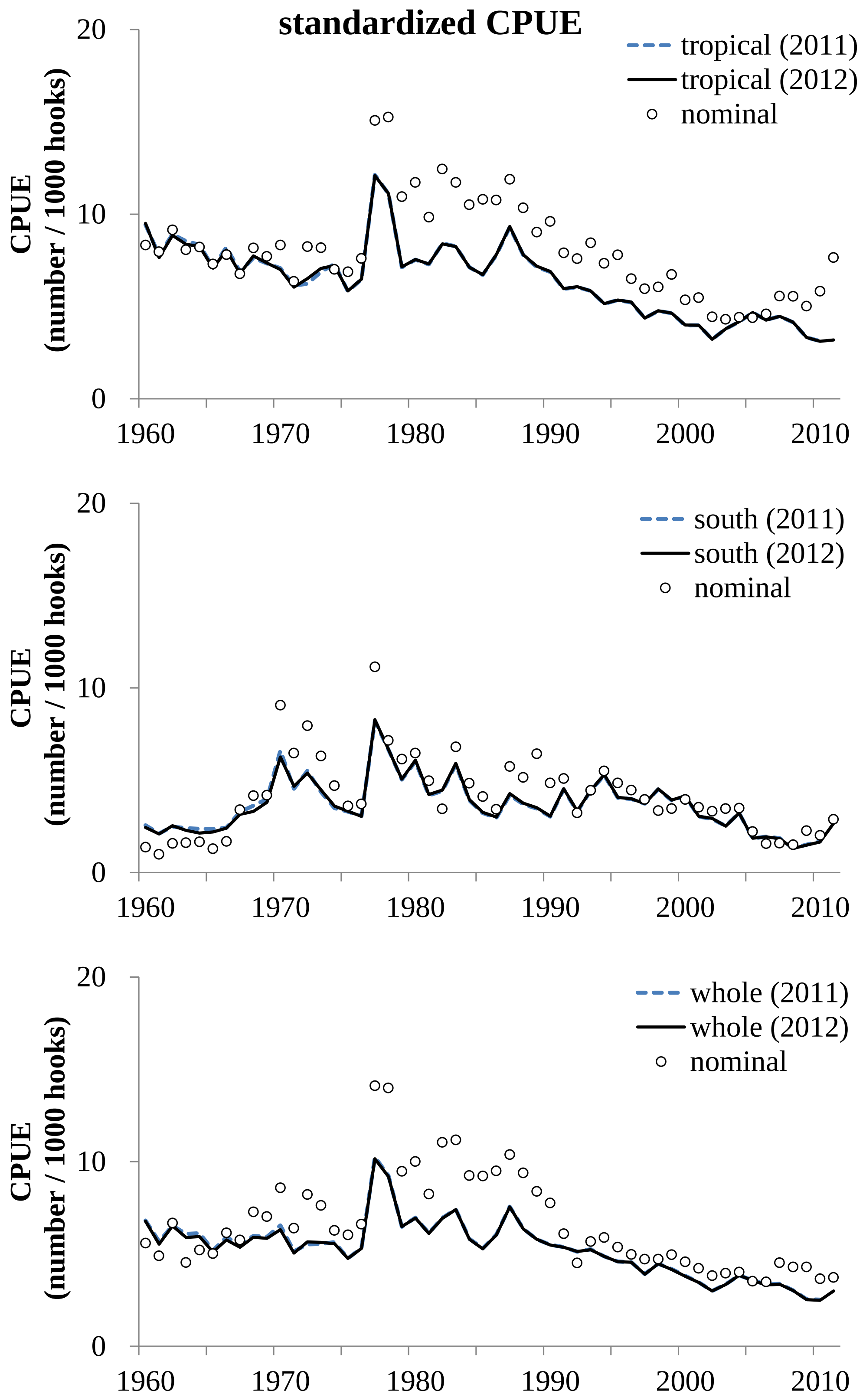


Fig. 2. Comparison of three CPUE series of bigeye. Standardized CPUE in 2012 (solid line), nominal CPUE (open circle), and standardized CPUE in 2011 (dashed line) of Japanese longline for the tropical (top), south (middle) and whole (bottom) Indian Ocean.

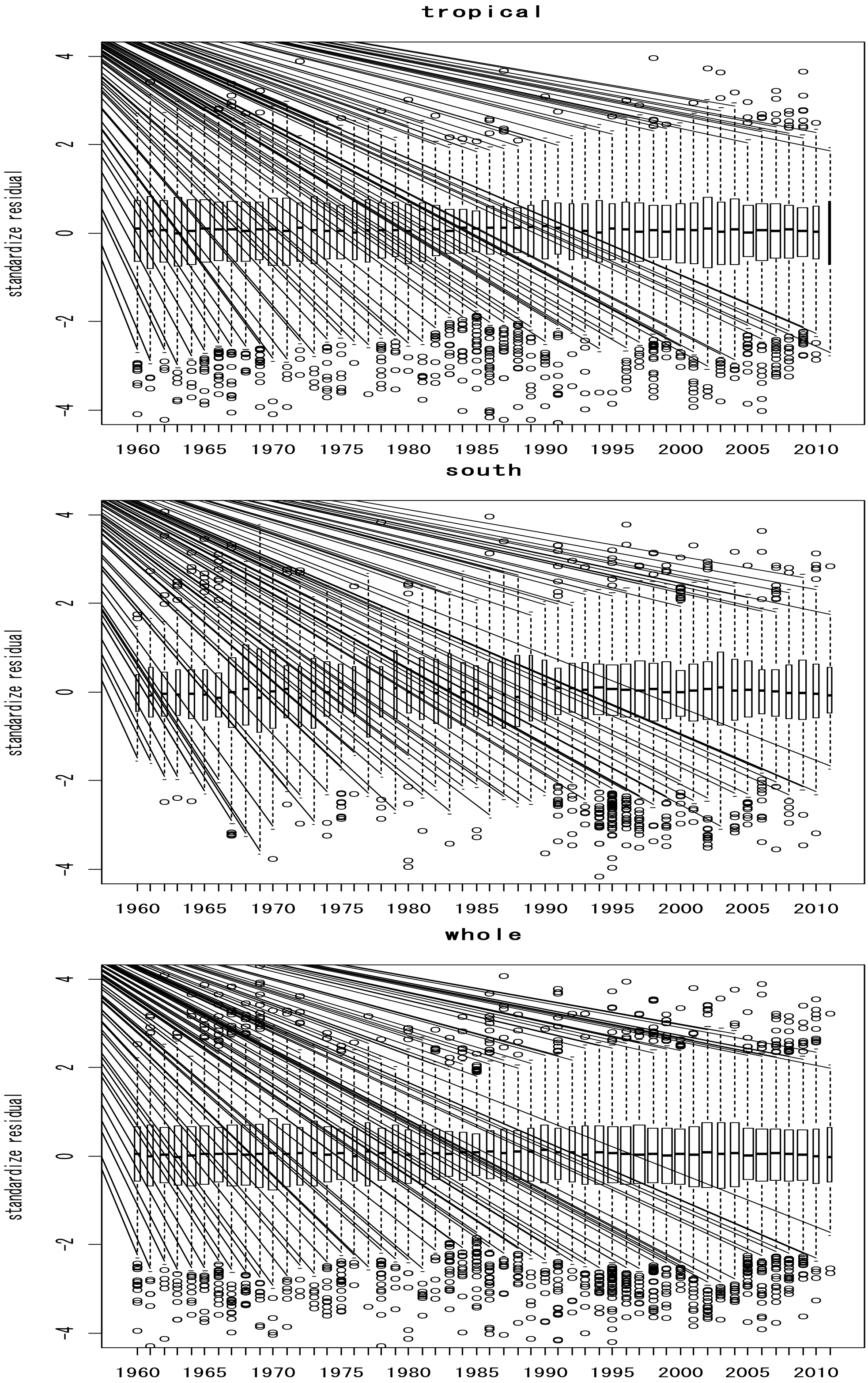


Fig. 3. Standardized residuals by year for each region (tropical (top), south (middle) and whole (bottom) Indian Ocean). Box-plot (box; 25percentile – median (horizontal line) – 75 percentile, dashed line; x1.5 of (75 percentile-25 percentile), open circle; outlier).

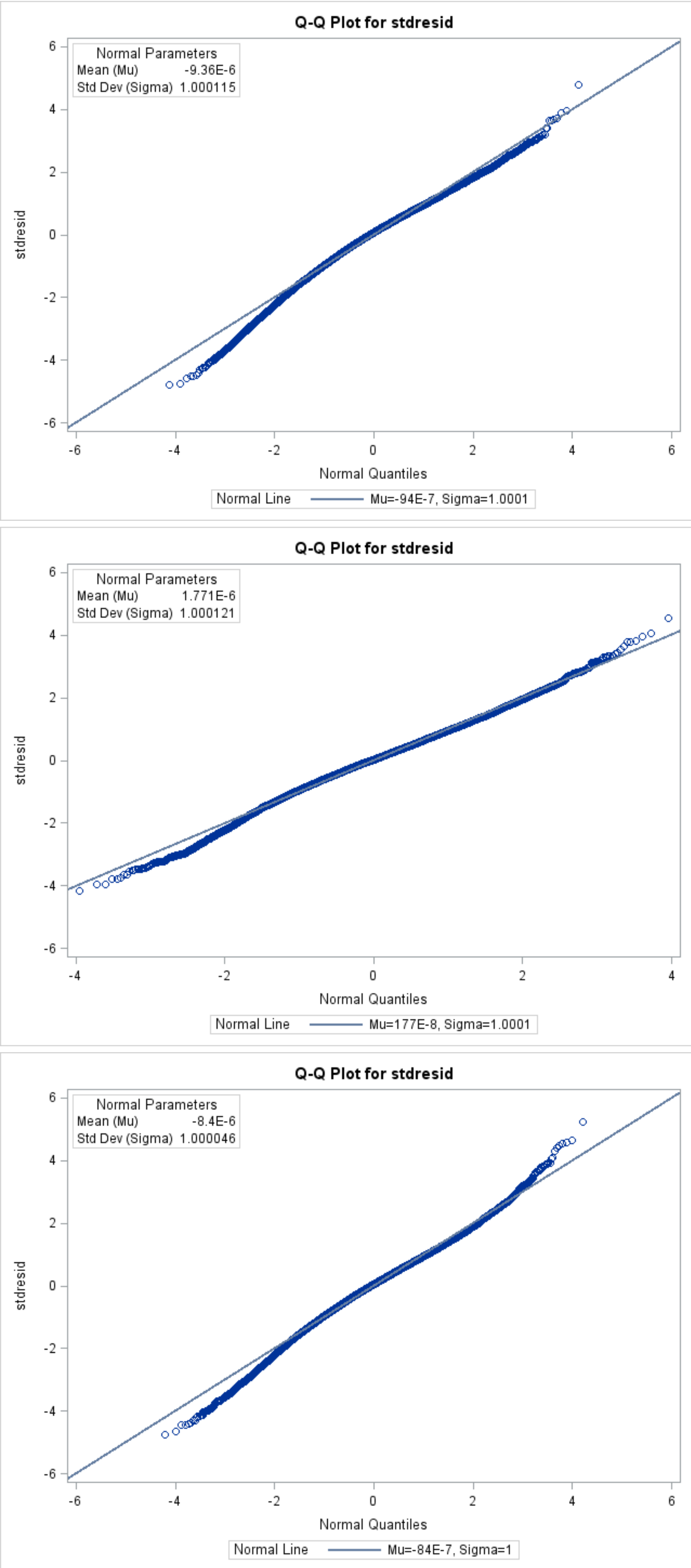


Fig. 4. QQ-plots for standardized residuals of each region (tropical (top), south (middle) and whole (bottom) Indian Ocean).

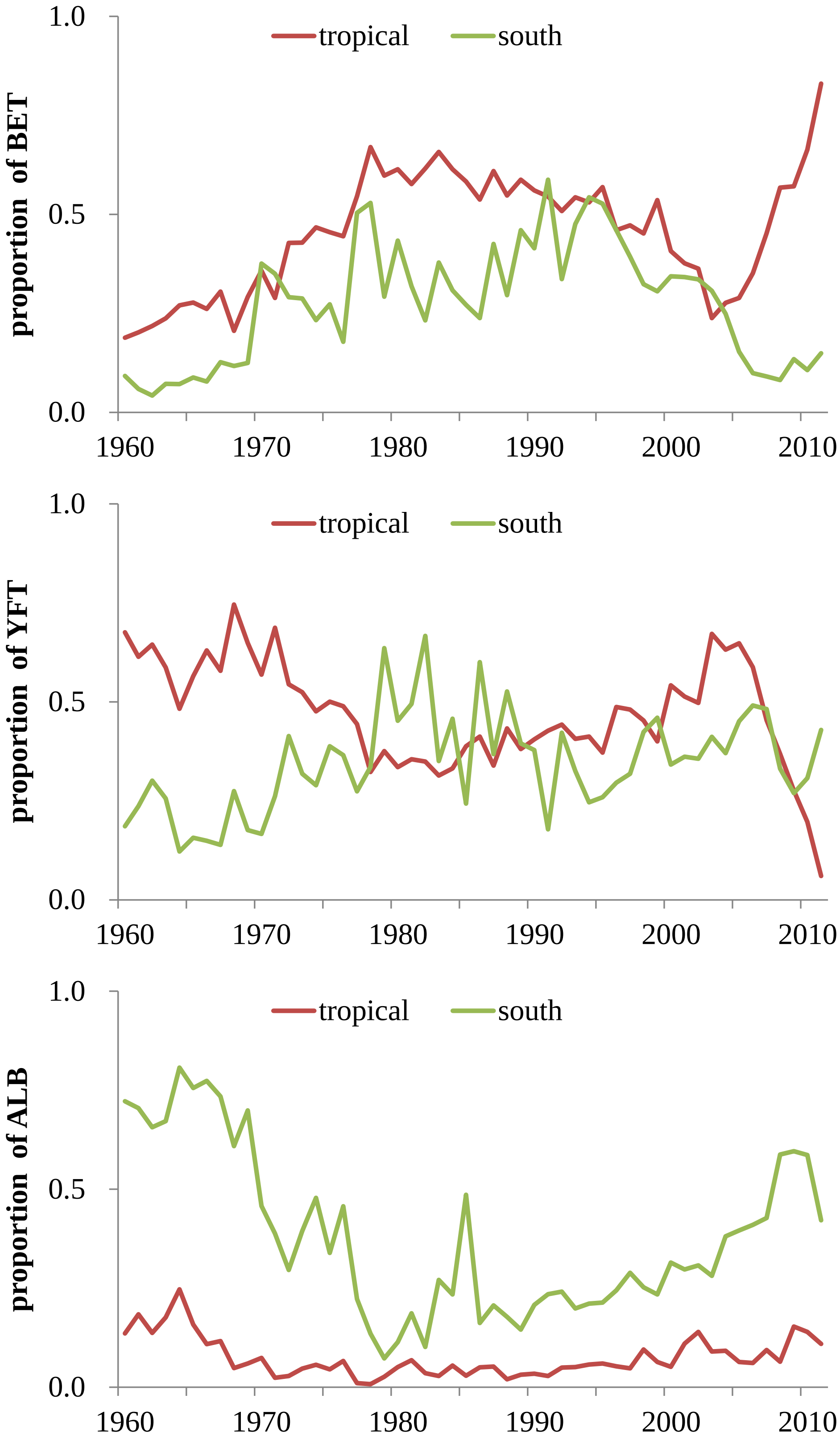
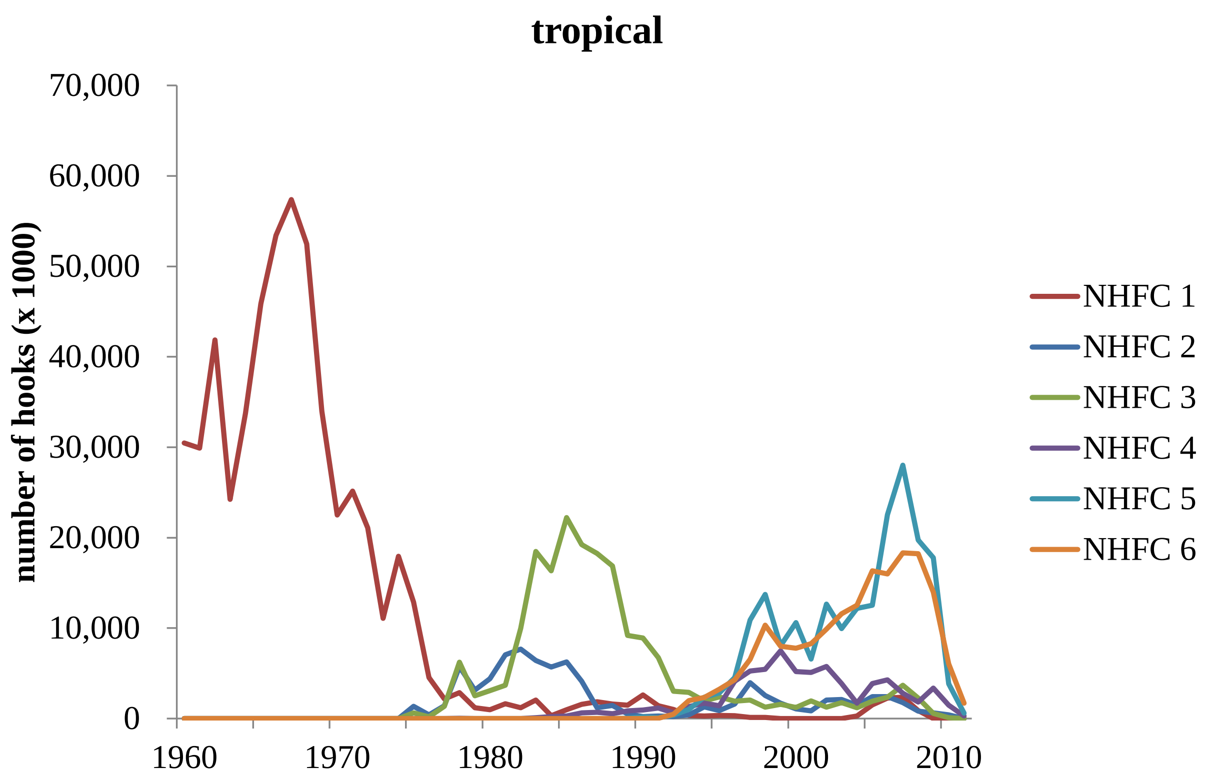


Fig. 5 Annual proportion of BET (bigeye tuna, upper panel), YFT (yellowfin tuna, middle) and ALB (albacore, lower) of Japanese longline in the Indian Ocean from 1960 to 2011. Proportion for BET = BET / (BET +YFT + ALB) in number.



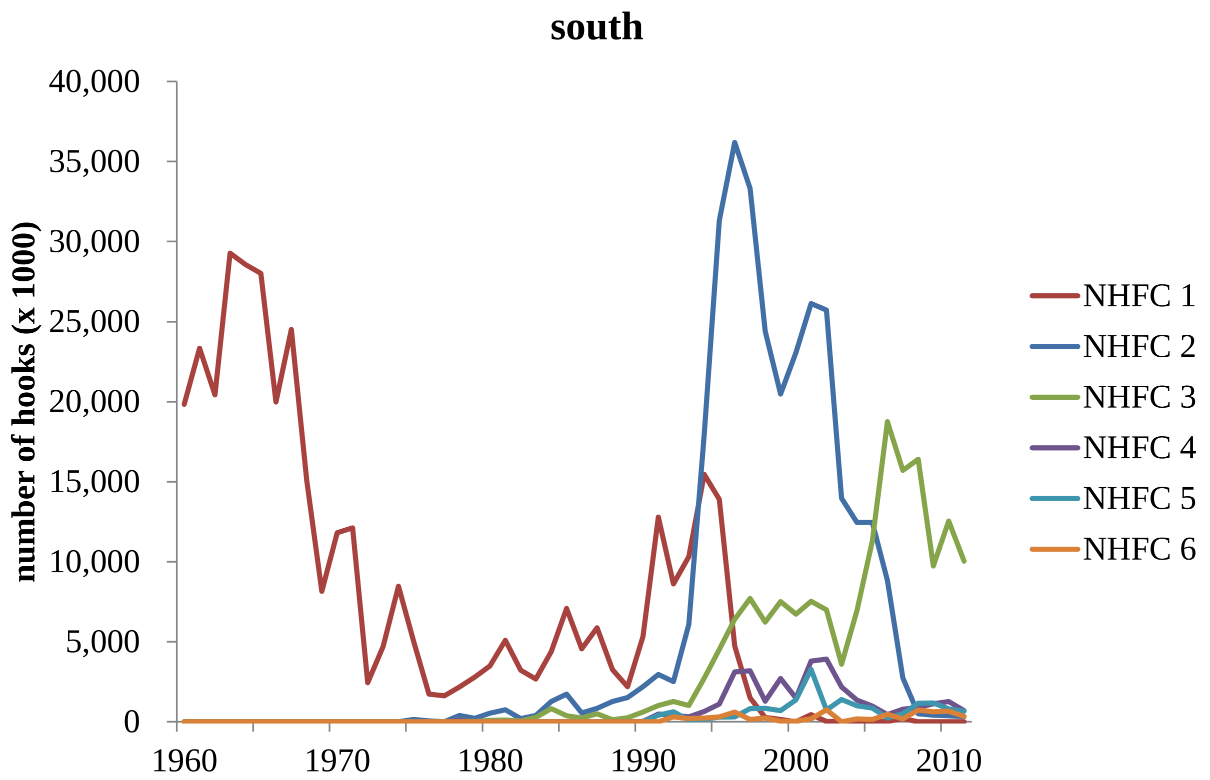


Fig. 6 Historical changes of number of hooks by NHFC by region (tropical and south) of Japanese longline in the Indian Ocean from 1960 to 2011. The number of hooks between float (NHF) was divided into 6 classes (NHFC 1: 5-7, NHFC 2: 8-10, NHFC 3: 11-13, NHFC 4: 14-16, NHFC 5: 17-19, NHFC 6: 20-21).

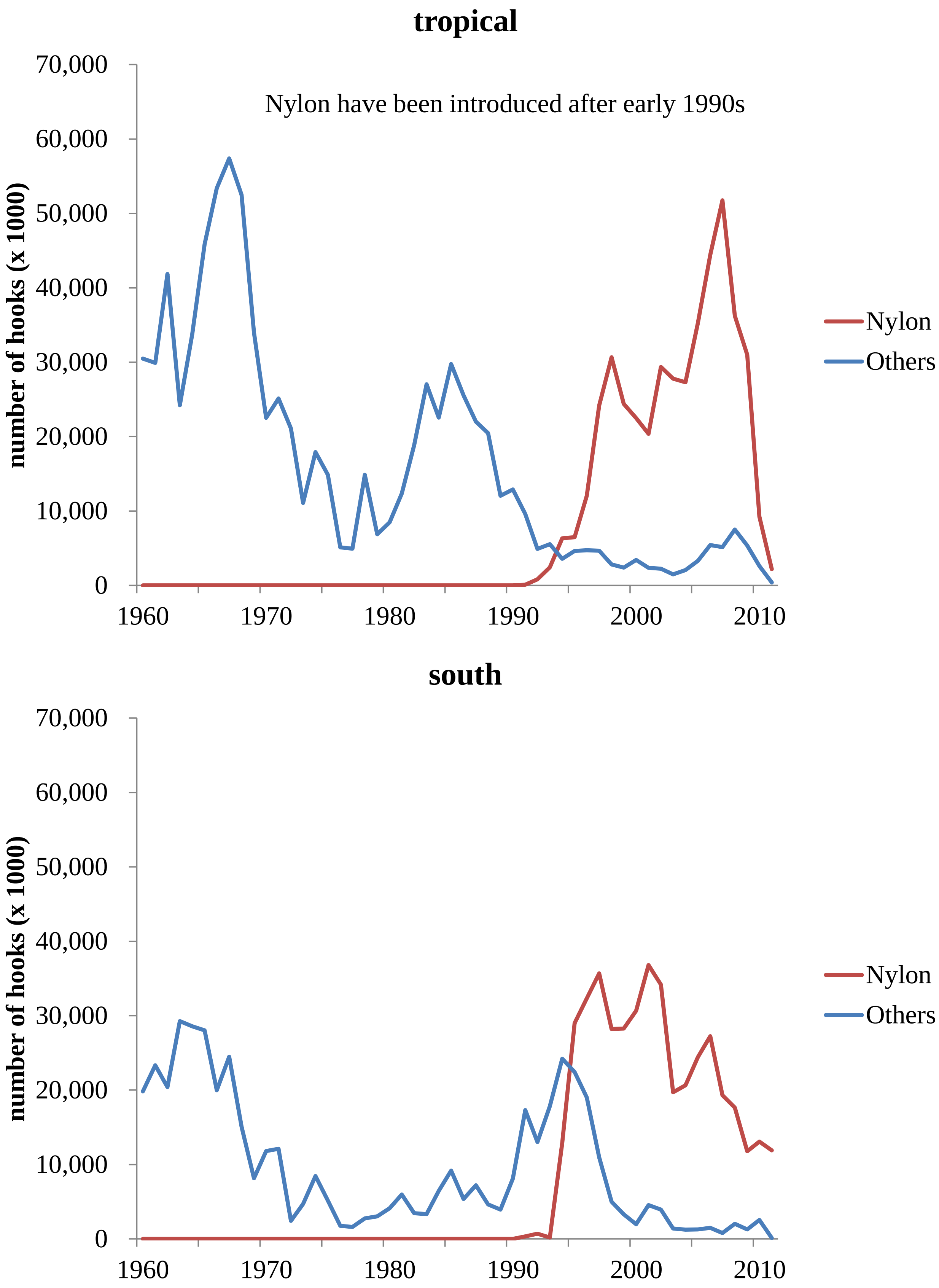


Fig. 7 Historical changes of number of hooks by material of main line (Nylon, others) of Japanese longline in the Indian Ocean from 1960 to 2011.

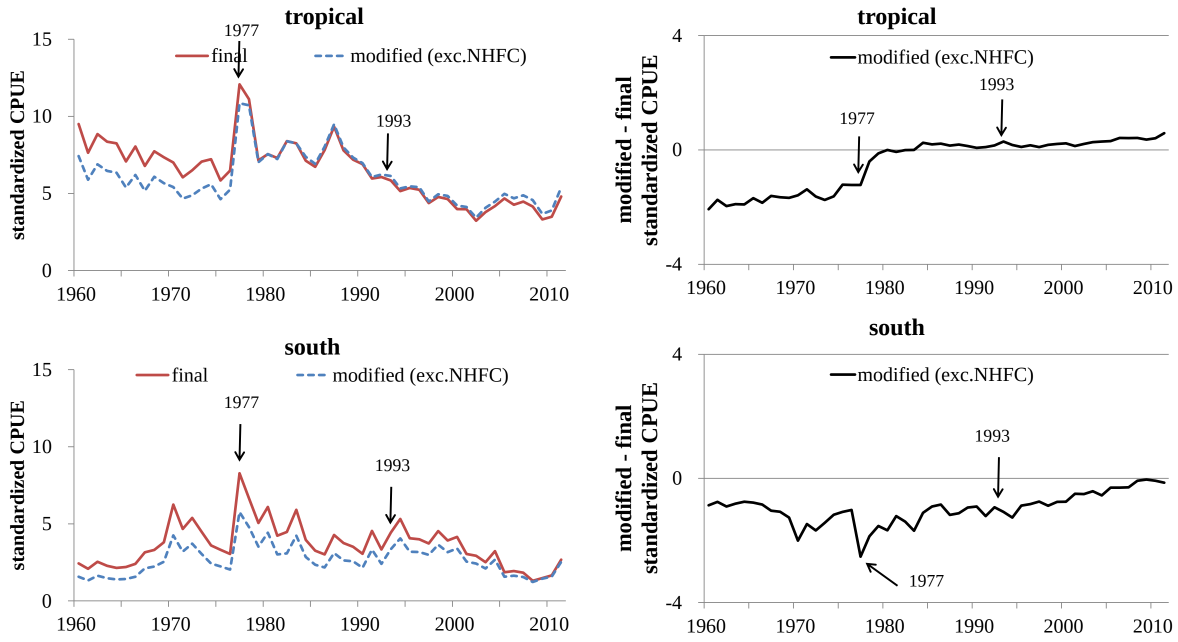


Fig. 8 Historical changes of standardized CPUE of Japanese longline in the Indian Ocean from 1960 to 2011 for the final model and the modified model (excluding variable “NHFC” form the final model) by region in right two panels. Differences between the final model and the modified model by region in left two panels. Tropical region; upper two panels, south region; lower two panels.

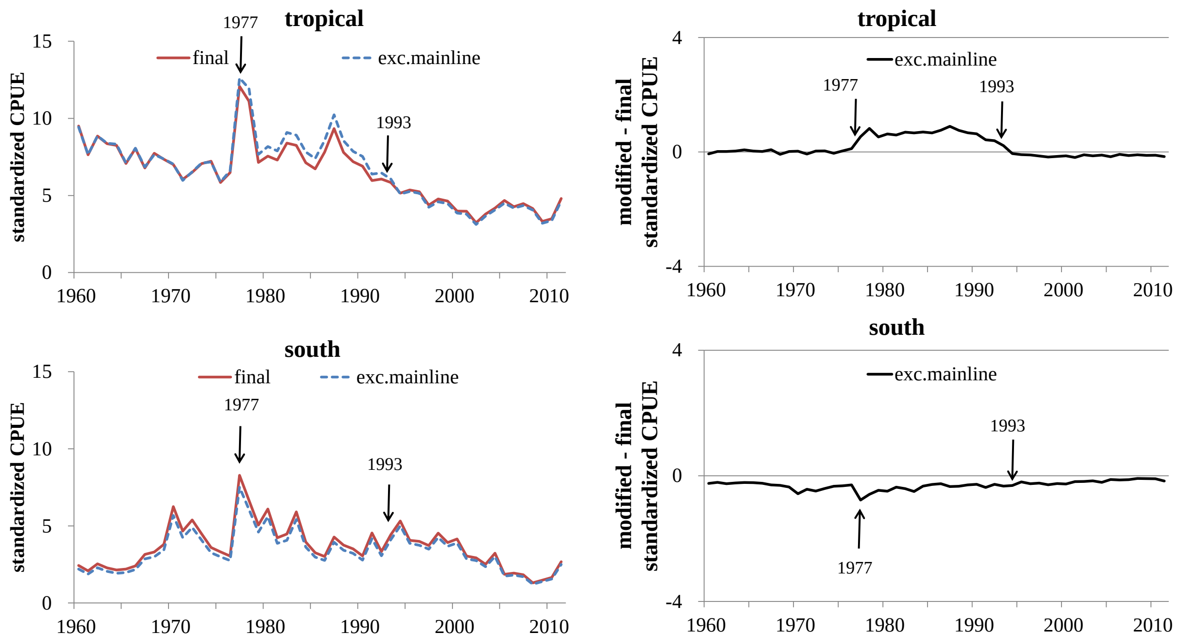


Fig. 9 Historical changes of standardized CPUE of Japanese longline in the Indian Ocean from 1960 to 2011 for the final model and the modified model (excluding variable “main line” form the final model) by region in right two panels. Differences between the final model and the modified model by region in left two panels. Tropical region; upper two panels, south region; lower two panels.

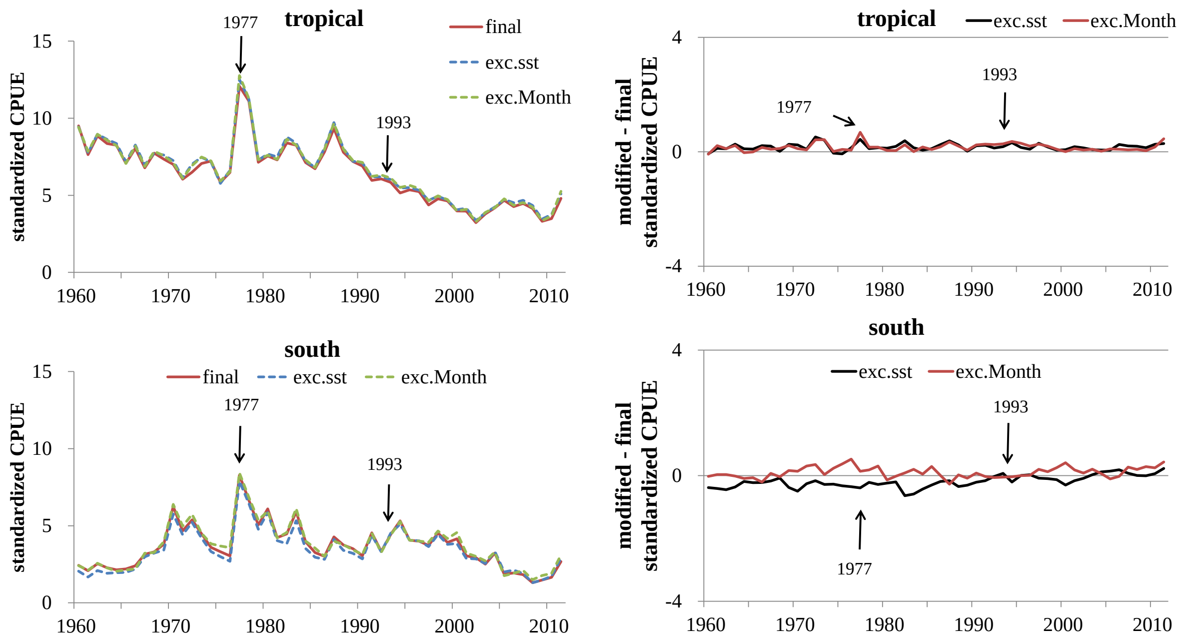


Fig. 10 Historical changes of standardized CPUE of Japanese longline in the Indian Ocean from 1960 to 2011 for the final model and the modified model (excluding variable “SST” (sea surface temperature) and “month” form the final model) by region in right two panels. Differences between the final model and the modified model by region in left two panels. Tropical region; upper two panels, south region; lower two panels.

Appendix Table 1. Annual value of standardized bigeye tuna CPUE in the tropical, south and whole Indian Ocean from 1960-2011 expressed in real and relative scale in which the average from 1960 to 2011 is 1.0, with squared standard error of log CPUE (= CV of CPUE).

tropical				**south**				**whole**			
year	CPUE	CV	Relative CPUE	year	CPUE	CV	Relative CPUE	year	CPUE	CV	Relative CPUE
1960	9.5050	0.0012	1.4697	1960	2.4373	0.0073	0.6702	1960	6.7738	0.0013	1.2839
1961	7.6404	0.0014	1.1814	1961	2.0839	0.0052	0.5730	1961	5.5333	0.0011	1.0488
1962	8.8546	0.0009	1.3691	1962	2.5373	0.0038	0.6977	1962	6.5171	0.0008	1.2353
1963	8.3626	0.0011	1.2930	1963	2.2806	0.0036	0.6271	1963	5.8923	0.0009	1.1168
1964	8.2536	0.0009	1.2762	1964	2.1402	0.0036	0.5885	1964	5.9428	0.0008	1.1264
1965	7.0759	0.0007	1.0941	1965	2.2002	0.0034	0.6050	1965	5.1072	0.0007	0.9680
1966	8.0511	0.0007	1.2449	1966	2.4064	0.0039	0.6617	1966	5.7607	0.0007	1.0919
1967	6.7802	0.0007	1.0484	1967	3.1528	0.0026	0.8669	1967	5.3667	0.0006	1.0172
1968	7.7384	0.0009	1.1965	1968	3.3054	0.0027	0.9089	1968	5.9077	0.0007	1.1198
1969	7.3484	0.0008	1.1362	1969	3.7995	0.0032	1.0447	1969	5.8475	0.0007	1.1083
1970	7.0075	0.0010	1.0835	1970	6.2509	0.0030	1.7188	1970	6.3207	0.0008	1.1980
1971	6.0493	0.0009	0.9353	1971	4.6680	0.0033	1.2836	1971	5.0518	0.0007	0.9575
1972	6.5074	0.0014	1.0062	1972	5.3865	0.0066	1.4811	1972	5.6562	0.0013	1.0721
1973	7.0667	0.0014	1.0927	1973	4.4792	0.0053	1.2316	1973	5.6236	0.0012	1.0659
1974	7.2225	0.0013	1.1167	1974	3.5953	0.0036	0.9886	1974	5.5571	0.0009	1.0533
1975	5.8449	0.0013	0.9037	1975	3.3155	0.0045	0.9117	1975	4.7582	0.0010	0.9019
1976	6.4810	0.0022	1.0021	1976	3.0492	0.0113	0.8384	1976	5.3038	0.0021	1.0053
1977	12.0838	0.0029	1.8684	1977	8.2850	0.0172	2.2781	1977	10.1585	0.0030	1.9255
1978	11.1205	0.0013	1.7194	1978	6.6603	0.0066	1.8314	1978	9.1921	0.0013	1.7423
1979	7.1482	0.0031	1.1053	1979	5.0598	0.0064	1.3913	1979	6.4853	0.0021	1.2292
1980	7.5517	0.0017	1.1676	1980	6.0907	0.0061	1.6747	1980	6.9443	0.0014	1.3162
1981	7.3034	0.0011	1.1292	1981	4.2300	0.0045	1.1631	1981	6.1084	0.0010	1.1578
1982	8.3952	0.0008	1.2981	1982	4.4717	0.0073	1.2296	1982	6.9362	0.0011	1.3147
1983	8.2505	0.0011	1.2757	1983	5.9145	0.0056	1.6263	1983	7.3968	0.0011	1.4020
1984	7.1261	0.0013	1.1018	1984	3.9544	0.0036	1.0873	1984	5.7998	0.0010	1.0993
1985	6.7300	0.0011	1.0406	1985	3.2563	0.0039	0.8954	1985	5.2750	0.0009	0.9998
1986	7.8141	0.0007	1.2082	1986	3.0113	0.0053	0.8280	1986	6.0273	0.0009	1.1424
1987	9.3360	0.0008	1.4435	1987	4.2788	0.0046	1.1765	1987	7.5456	0.0009	1.4302
1988	7.7971	0.0010	1.2056	1988	3.7522	0.0071	1.0317	1988	6.3496	0.0012	1.2035
1989	7.1898	0.0011	1.1117	1989	3.5145	0.0072	0.9664	1989	5.7995	0.0012	1.0992
1990	6.8984	0.0010	1.0666	1990	3.0537	0.0048	0.8397	1990	5.4809	0.0010	1.0389
1991	5.9687	0.0013	0.9229	1991	4.5429	0.0023	1.2492	1991	5.3629	0.0009	1.0165
1992	6.0704	0.0017	0.9386	1992	3.3347	0.0036	0.9169	1992	5.1298	0.0012	0.9723
1993	5.8468	0.0013	0.9040	1993	4.4380	0.0023	1.2203	1993	5.2262	0.0009	0.9906
1994	5.1529	0.0010	0.7967	1994	5.3146	0.0013	1.4613	1994	4.8689	0.0007	0.9229
1995	5.3550	0.0008	0.8280	1995	4.0645	0.0009	1.1176	1995	4.5805	0.0006	0.8682
1996	5.2452	0.0006	0.8110	1996	3.9960	0.0010	1.0988	1996	4.5557	0.0005	0.8635
1997	4.3770	0.0004	0.6768	1997	3.7289	0.0012	1.0253	1997	3.8982	0.0004	0.7389
1998	4.7711	0.0005	0.7377	1998	4.5306	0.0022	1.2458	1998	4.4676	0.0005	0.8468
1999	4.6335	0.0005	0.7164	1999	3.9198	0.0020	1.0778	1999	4.1507	0.0005	0.7867
2000	3.9921	0.0005	0.6173	2000	4.1485	0.0015	1.1407	2000	3.7926	0.0004	0.7189
2001	3.9819	0.0006	0.6157	2001	3.0475	0.0011	0.8380	2001	3.4481	0.0005	0.6536
2002	3.2265	0.0005	0.4989	2002	2.9295	0.0013	0.8055	2002	2.9943	0.0004	0.5675
2003	3.7978	0.0012	0.5872	2003	2.5150	0.0027	0.6915	2003	3.3496	0.0009	0.6349
2004	4.1796	0.0008	0.6462	2004	3.2265	0.0029	0.8872	2004	3.8389	0.0007	0.7276
2005	4.6722	0.0013	0.7224	2005	1.8641	0.0031	0.5126	2005	3.5641	0.0010	0.6755
2006	4.2645	0.0006	0.6594	2006	1.9388	0.0029	0.5331	2006	3.3202	0.0006	0.6293
2007	4.4702	0.0004	0.6912	2007	1.8329	0.0027	0.5040	2007	3.3607	0.0005	0.6370
2008	4.1513	0.0004	0.6419	2008	1.3051	0.0019	0.3588	2008	3.0162	0.0005	0.5717
2009	3.3176	0.0006	0.5130	2009	1.4826	0.0022	0.4077	2009	2.5203	0.0006	0.4777
2010	3.4925	0.0014	0.5400	2010	1.6597	0.0020	0.4564	2010	2.6739	0.0010	0.5068
2011	4.8078	0.0057	0.7434	2011	2.6711	0.0036	0.7345	2011	3.8067	0.0025	0.7215