

**Standardized Japanese longline CPUE for bigeye tuna
in the Indian Ocean up to 2002
with consideration on gear categorization**

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Abstract

Japanese longline CPUE for bigeye tuna from 1960 to 2002 was standardized by GLM (CPUE-LogNormal error structured model) which SST (Sea Surface Temperature) and MLD (Mixed Layer Depth) were included in the model as oceanographic factors. NHF (Number of Hooks between Float) which was divided into three classes in the previous study was classified into six categories in this study. In the tropical area, the main longline fishing ground for bigeye, the CPUE has continuously declined since 1960 except for 1977 and 1978. The declining trend after 1987 is remarkable, and the lowest CPUE has been recorded year by year in recent ten years. Although the relative CPUE fluctuated drastically, and no clear trend was observed in the temperate area, obvious declining trend has been observed since 1994. Since Catch model with Negative Binomial error structure also applied for comparison, the relative trend was quite similar with that from CPUE-LogNormal model.

1. Introduction

In the standardization of bigeye CPUE of Japanese longline fishery conducted in 2001 (Okamoto et al. 2001), SST (Sea Surface Temperature) and SOI (Southern Oscillation Index) were applied to GLM (CPUE-LogNormal error structure assumption) as the oceanographic factors. In 2002, MLD (Mixed Layer Depth) was applied instead of SOI to reflect the oceanographic condition more accurately in the standardization (Okamoto and Miyabe 2003). In this paper, the CPUE was standardized up to 2002 applying the almost same model used in 2002 except for change in the categorization of the NHF (Number of Hooks between Float). Additionally, Negative Binomial error structure assumption was also applied for comparison.

2. Materials and methods

Area definition:

Area definition used in this study was the same as that revised in Okamoto et al. (2001) as shown in Fig. 1. Main fishing ground of Japanese longline fishery was divided into seven sub-areas and CPUE standardization was done for three cases of the sub-area combinations, Tropical (sub-areas 1-5), South (sub-areas 6 & 7) and ALL (sub-areas 1-7) Indian Ocean.

Environmental factors:

As environmental factors, which are available for the analyzed period from 1960 to 2002, SST (Sea Surface Temperature) and MLD (Mixed Layer Depth) were applied.

1) SST

The original SST data, whose resolution is 2-degree latitude and 2-degree longitude by month from 1946 to 2002, 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-degree longitude by month from 1960 to 2002 using the procedures described in Okamoto et al. (2001), and used in the analyses.

2) MLD (Mixed Layer Depth)

MLD data from 1960 to 2002 was downloaded from JEDAC (Joint Environmental Data Analysis Center) website of Scripps Institution of Oceanography.

http://jedac.ucsd.edu/DATA_IMAGES/index.html

The Original MLD data, which the resolution is 2-degree latitude and 5-degree longitude (corner of grid) by month, was recompiled to 5-degree latitude and 5-degree longitude (center of grid) by month using the similar procedure used for SST. In the case there were strata in which MLD data was not exist in spite of that the longline operations were made in the strata, substitution of MLD data was made by selecting appropriate values from nearby strata to fill the strata.

Catch and effort data used:

The Japanese longline catch (in number) and effort statistics from 1960 up to 2002 were used. 2002 data is preliminary. The catch and effort data set from aggregated by month, 5-degree square and the number of hooks between floats (NHF), was used for the analysis. Data in strata in which the number of hooks was less than 10000 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.

GLM (Generalized Linear Model):

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-LogNormal error structured model) with SST and MLD was as follows.

Model (CPUE-LogNormal error structured model):

$$\text{Log (CPUE}_{ijkl} + \text{const}) = \mu + \text{YR}_{(i)} + \text{MN}_{(j)} + \text{AREA}_{(k)} + \text{NHF}_{(l)} + \text{SST}_{(m)} + \text{MLD}_{(n)} + \text{YR}_{(i)} * \text{AREA}_{(k)} + \text{MN}_{(j)} * \text{AREA}_{(k)} + \text{AREA}_{(k)} * \text{NHF}_{(l)} + \text{AREA}_{(k)} * \text{SST}_{(m)} + \text{AREA}_{(k)} * \text{MLD}_{(n)} + \text{SST}_{(m)} * \text{MLD}_{(n)} + e_{(ijkl...)}$$

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),

$\text{YR}_{(i)}$: effect of year,

$\text{MN}_{(j)}$: effect of fishing season (month),

$\text{AREA}_{(k)}$: effect of sub-area,

$\text{NHF}_{(l)}$: effect of gear type (class of the number of hooks between floats),

$\text{SST}_{(m)}$: effect of SST,

$\text{MLD}_{(n)}$: effect of MLD,

$\text{YR}_{(i)} * \text{AREA}_{(k)}$: interaction term between year and sub-area,

$\text{MN}_{(j)} * \text{AREA}_{(k)}$: interaction term between fishing season and sub-area,

$\text{AREA}_{(k)} * \text{NHF}_{(l)}$: interaction term between sub-area and gear type,

$\text{AREA}_{(k)} * \text{SST}_{(m)}$: interaction term between sub-area and SST,

$\text{AREA}_{(k)} * \text{MLD}_{(n)}$: interaction term between sub-area and MLD,

$\text{SST}_{(m)} * \text{MLD}_{(n)}$: interaction term between SST and MLD,

$e_{(ijkl...)}$: error term.

The number of hooks between float (NHF) was divided into 6 classes (NHFCL 1: 5-7, NHFCL 2: 8-10, NHFCL 3: 11-13, NHFCL 4: 14-16, NHFCL 5: 17-19, NHFCL 6: 20-21) as later explanation.

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

$$CPUE_i = \sum W_j * (\exp(\text{lsmean}(\text{Year } i * \text{Area } j)) - \text{constant})$$

Where $CPUE_i$ = CPUE in year i ,

$$W_j = \text{Area rate of Area } j, (\sum W_j = 1),$$

$\text{lsmean}(\text{Year} * \text{Area}_{ij})$ = least square mean of Year-Area interaction in Year i and Area j ,

constant = 10% of overall mean of CPUE.

3. Results and discussion

Historical change in the NHF (the number of hooks between float):

In the previous studies (Okamoto et al. 2001, Okamoto and Miyabe 2003), NBF were divided into three categories, NHFCL1 (NHF: 5-9, regular set), NHFCL2 (NHF: 10-15, deep set) and NHFCL3 (NHF: 16-21, very deep). In the WPM (Working Party on Method) convened in 2001, it was pointed out by a participant that the distribution of the 'very deep' effort in the recent period coincides with areas where BET had been targeted in earlier periods and that effort considered as 'deep' is deployed in the southern areas, where the primary target species is known not to be bigeye tuna. We will check if this is the case. In the Fig. 2, historical changes in the frequency of three NHFCLs were shown for Tropical, Temperate and ALL Indian Ocean. In the tropical area, target was rapidly shifted from yellowfin to bigeye in the middle 1970s (Suzuki et al. 1977) and ratio of regular (NHFCL1) set decreased from 100% in 1975 to around 15% in early 1980s. Accordingly, the ratio of deep set (NHFCL2) increased to 90% in this period. In the early 1990s, 'very deep' set (NHFCL3) was introduced and increased up to 70-80% in the recent years while the ratio of deep and regular sets have been decreased to 20-30% and nearly 0%, respectively. In the temperate area, remarkable change in gear configuration did not occur until late 1980s when the regular set started to decrease and have been replaced by deep set. These change indicated in the figure coincide well with the point mentioned previously. If this change in NHFCL is simply interpreted, the target species must have changed in late 1980s in the temperate area. In the Fig. 3, historical change in the frequency of each NHF was shown. Although the decrease of NHF 5 and 6 in the tropical area in the middle 1970s was relatively steep, since then the major NHF has been shifted from NHH=10 to NHF=20. In the case of temperate area, the shifts of major NHF were also observed, but they have taken longer years. When the historical change of the major NHF was traced (Fig. 4), abrupt increase of NHF was observed in 1994 and 1995 in tropical and temperate areas, that is, from NHF=13 to NHF=20 in the tropical and from NHF=7 to NHF=10 in the temperate. NHF larger than 18-20 and that 9-10 were started to be used around 1992 in tropical and temperate areas, respectively (Fig. 3), and this period coincide with the period when the Nylon mono-filament has become a popular material of main and branch lines. The material information for main and branch lines has been included in logbook data since 1994. Fig. 5 shows the change in the frequency of the Nylon-monofilament mainline from 1994 to 2001 by six classes of NHF (NHFCL 1: 5-7, NHFCL 2: 8-10, NHFCL 3: 11-13, NHFCL 4: 14-16, NHFCL 5: 17-19, NHFCL 6: 20-21). Almost all mainline of NHFCL6 was already Nylon mono-filament in 1994, while the other categories of NHFCL is also showing increasing trend in frequency of this material. According to the information from an expert of longline operation, it was impossible to make operation with larger than NHF=17 by using ordinary mainline whose diameter is 7.9mm because the gear weight per basket is too heavy to be sustained by normal float. Therefore, the rapid increase of NHF which started around 1992 seems to be derived from the introduction of the new material.

In summary, after the great shift of targeting around 1975, major NHF used was gradually changed to large NHF until early 1990 especially in the tropical area. And the major NHF started quick shift to much larger NHF in early 1990's. This quick shift seems to be caused by the introduction of new material for mainline (and branch line also). Since the use of the new material was mainly used for the operation of NHF larger than 18 or so, it has become popular also for the smaller NHF operations. Considering the gradual change in NHF and the heterogeneity of the 'very deep' set, it would be better to categorize NHF into not only DEEP and REGULAR (and VERY DEEP) but into more categories as far as each of them

includes enough observations. Then, NHF was divided into six NHFCLs and applied into GLM in this study. Historical change in ratio of the six NHFCLs can be referred in Fig. 6. However, the actual effect of the introduction of the new material on the bigeye CPUE has not been studied enough and would be next issue to be surveyed.

CPUE standardizations by GLM:

The bigeye CPUE (catch in number per 1000 hooks) was standardized by GLM (CPUE-LogNormal error structured model) described in the materials and method section. Results of ANOVA and distributions of the standard residual in each analysis were shown in Table 1 and Fig. 7, respectively. Distributions of the standard residual did not show remarkable difference from the normal distribution.

Trends of relative CPUE in each area category (Tropical, South and All Indian Ocean) were shown in Fig. 8 overlaying the results from previous model in which NHB was classified three categories. In the temperate area, their trends were quite similar. In the tropical area, relative CPUE before 1976 became higher and that after 1978 became lower in this study. As a result, a gap of CPUE which was observed between these periods came to be smaller or disappeared although highly protrude CPUE in 1977 and 1978 still exists. In the tropical area, the main longline fishing ground for bigeye, the CPUE has continuously declined since 1960 except for 1977 and 1978. The declining trend after middle of 1980's is remarkable, and the lowest CPUE has been recorded year by year in a latest decade. Although the relative CPUE fluctuated drastically, and no clear trend was observed in the temperate area, obvious declining trend has been observed since 1994. Considering that the temperate area is not major fishing ground for bigeye, and that real scaled CPUE in this area is less than half of that in the tropical area, it would be better to refer the CPUE in the tropical area to grasp the abundance trend of this species. Even if the CPUE estimated for all Indian Ocean (sub-area 1-7) is referred, that after 1994 is the lowest level in the Japanese longline history in this Ocean. Annual values of standardized CPUE by area were listed in Appendix table. Standardized CPUE of each month and each NHFCL were compared for tropical and temperate area in Fig. 9. In the temperate, CPUE was highest in summer (Jun-Sep) and lowest in winter (Nov-Feb). Although the seasonal trend in tropical was not so clear, that in winter was highest in winter and lowest in March and April. Regarding NHFCL, larger NHBCL shows higher CPUE though that of NHFCL 6 was slightly lower than that of NHFCL 4 and 5. Since the same trend was recognized also in temperate, difference between NHFCL was smaller than that in tropical.

Finally, the results of the standardization applying Catch model with Negative Binomial error structure were shown in Fig. 10 overlaid with those from CPUE-LogNormal error structured model just for comparison. In the Negative Binomial model, the same explanatory variables as that used in lognormal model were used without careful examine. Basic structure of the model was as follows.

$$E[\text{Catch}] = \text{Effort} * \exp(\text{Intercept} + \text{each explanatory variables})$$

where, Catch ~ Negative Binomial(α, β)

Their trends were almost same each other in tropical, temperate and all Indian Ocean.

4. Recerences

- Ogura, M. and H. Shono (1999): Factors affecting the fishing effort of the Japanese distant water pole and line vessel and the standardization of that skipjack CPUE, Part B. SCTB 12/SKJ-4, 16p.
- Okamoto, H., N. Miyabe and T. Matsumoto (2001): GLM analyses for standardization of Japanese longline CPUE for bigeye tuna in the Indian Ocean applying environmental factors. IOTC/TTWP-01-21, 38p.
- Okamoto, H. and N. Miyabe (2003): Standardized Japanese longline CPUE for bigeye tuna in the Indian Ocean up to 2001. IOTC/WPTT-03-11, 11p.
- Suzuki Z., Warashina Y., and Kishida M., 1977: The comparison of catches by regular and deep tuna longline gears in the western and central equatorial Pacific. Bull. *Far Seas Fish. Res. Lab.*, 15, 51-89.

IOTC-2004-WPTT-09

Table 1. ANOVA table of GLM using new model with six NHFCLs and old one with three NHFCLs.

	Model (bgnom a): New w ith six NHFCL						Model (bgnom a): Old w ith three NHFCL							
	Source	D.F.	S.S.	M.S.	F Value	Pr > F	R-Square	Source	D.F.	S.S.	M.S.	F Value	Pr > F	R-Square
TROPICAL	Model	305	3047.04	9.99	29.70	<.0001	0.343751	Model	290	1519.64	5.24	15.49	<.0001	0.346054
	Year	42	709.91	16.90	50.26	<.0001		Year	42	380.85	9.07	26.81	<.0001	
	Month	11	119.36	10.85	32.26	<.0001		Month	11	58.68	5.33	15.77	<.0001	
	Area	4	52.23	13.06	38.83	<.0001		Area	4	32.81	8.20	24.25	<.0001	
	NHFCL	5	129.29	25.86	76.88	<.0001		NHFCL	2	46.12	23.06	68.17	<.0001	
	SST	1	19.90	19.90	59.16	<.0001		SST	1	10.64	10.64	31.45	<.0001	
	MLD	1	3.16	3.16	9.40	0.0022		MLD	1	1.70	1.70	5.03	0.0249	
	Year*Area	168	472.81	2.81	8.37	<.0001		Year*Area	168	277.18	1.65	4.88	<.0001	
	Month*Area	44	156.50	3.56	10.58	<.0001		Month*Area	44	95.76	2.18	6.43	<.0001	
	Area*NHFCL	20	83.83	4.19	12.46	<.0001		Area*NHFCL	8	28.81	3.60	10.65	<.0001	
	Area*SST	4	55.62	13.91	41.34	<.0001		Area*SST	4	33.98	8.50	25.12	<.0001	
Area*MLD	4	13.89	3.47	10.33	<.0001		Area*MLD	4	7.28	1.82	5.38	0.0003		
SST*MLD	1	4.52	4.52	13.45	0.0002		SST*MLD	1	2.45	2.45	7.24	0.0071		
TEMPERATE	Model	122	6617.45	54.24	76.13	<.0001	0.408101	Model	116	3289.10	28.35	40.03	<.0001	0.412261
	Year	42	570.67	13.59	19.07	<.0001		Year	42	276.74	6.59	9.30	<.0001	
	Month	11	611.33	55.58	78.00	<.0001		Month	11	305.37	27.76	39.19	<.0001	
	Area	1	114.94	114.94	161.32	<.0001		Area	1	93.02	93.02	131.33	<.0001	
	NHFCL	5	68.74	13.75	19.30	<.0001		NHFCL	2	21.07	10.53	14.87	<.0001	
	SST	1	141.01	141.01	197.92	<.0001		SST	1	74.63	74.63	105.36	<.0001	
	MLD	1	539.26	539.26	756.88	<.0001		MLD	1	279.01	279.01	393.90	<.0001	
	Year*Area	42	198.08	4.72	6.62	<.0001		Year*Area	42	119.18	2.84	4.01	<.0001	
	Month*Area	11	328.20	29.84	41.88	<.0001		Month*Area	11	145.87	13.26	18.72	<.0001	
	Area*NHFCL	5	10.72	2.14	3.01	0.0102		Area*NHFCL	2	4.50	2.25	3.17	0.0419	
	Area*SST	1	258.49	258.49	362.80	<.0001		Area*SST	1	140.74	140.74	198.69	<.0001	
Area*MLD	1	0.19	0.19	0.26	0.6094		Area*MLD	1	0.66	0.66	0.93	0.3337		
SST*MLD	1	421.32	421.32	591.34	<.0001		SST*MLD	1	217.91	217.91	307.64	<.0001		
ALL_IND	Model	427	13431.23	31.45	68.68	<.0001	0.488003	Model	406	6623.67	16.31	35.62	<.0001	0.489051
	Year	42	839.18	19.98	43.63	<.0001		Year	42	440.00	10.48	22.88	<.0001	
	Month	11	119.37	10.85	23.69	<.0001		Month	11	57.13	5.19	11.34	<.0001	
	Area	6	190.80	31.80	69.43	<.0001		Area	6	126.76	21.13	46.13	<.0001	
	NHFCL	5	183.40	36.68	80.09	<.0001		NHFCL	2	62.69	31.34	68.44	<.0001	
	SST	1	13.10	13.10	28.60	<.0001		SST	1	7.43	7.43	16.23	<.0001	
	MLD	1	283.18	283.18	618.29	<.0001		MLD	1	146.95	146.95	320.88	<.0001	
	Year*Area	252	1113.85	4.42	9.65	<.0001		Year*Area	252	613.75	2.44	5.32	<.0001	
	Month*Area	66	774.12	11.73	25.61	<.0001		Month*Area	66	401.91	6.09	13.30	<.0001	
	Area*NHFCL	30	145.59	4.85	10.60	<.0001		Area*NHFCL	12	50.79	4.23	9.24	<.0001	
	Area*SST	6	354.55	59.09	129.02	<.0001		Area*SST	6	201.16	33.53	73.21	<.0001	
Area*MLD	6	54.15	9.03	19.71	<.0001		Area*MLD	6	26.40	4.40	9.61	<.0001		
SST*MLD	1	322.30	322.30	703.72	<.0001		SST*MLD	1	168.09	168.09	367.03	<.0001		

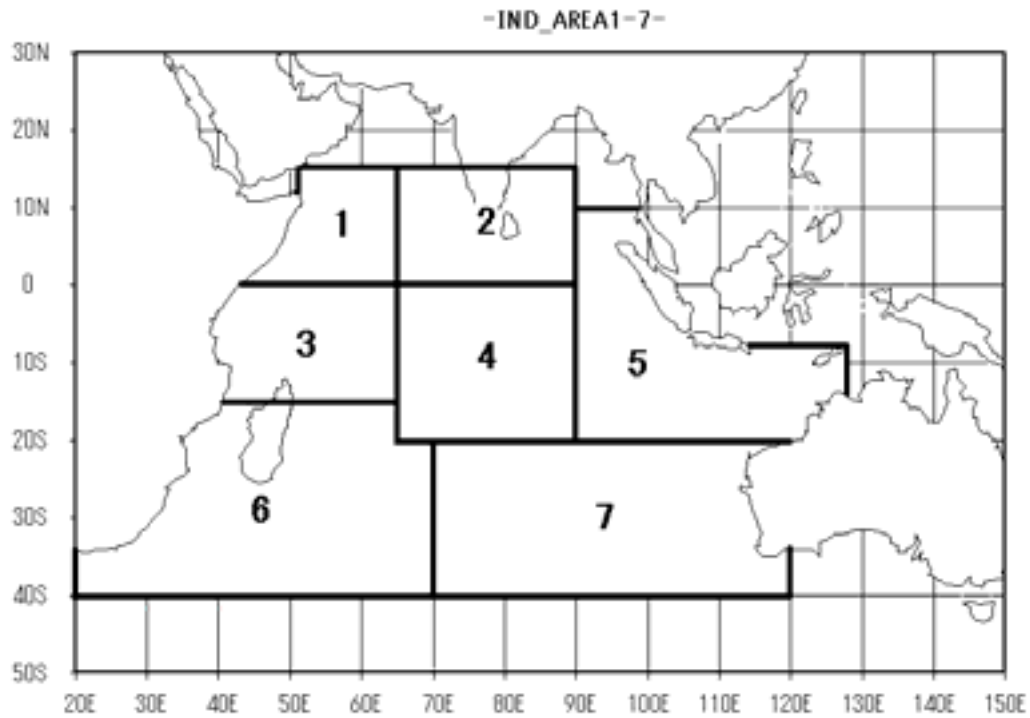


Fig. 1 Definition of sub-areas used in this study. TROPICAL, SOUTH and ALL INDIAN area categories in this paper consist of sub-areas 1-5, sub-areas 6-7 and sub-areas 1-7, respectively.

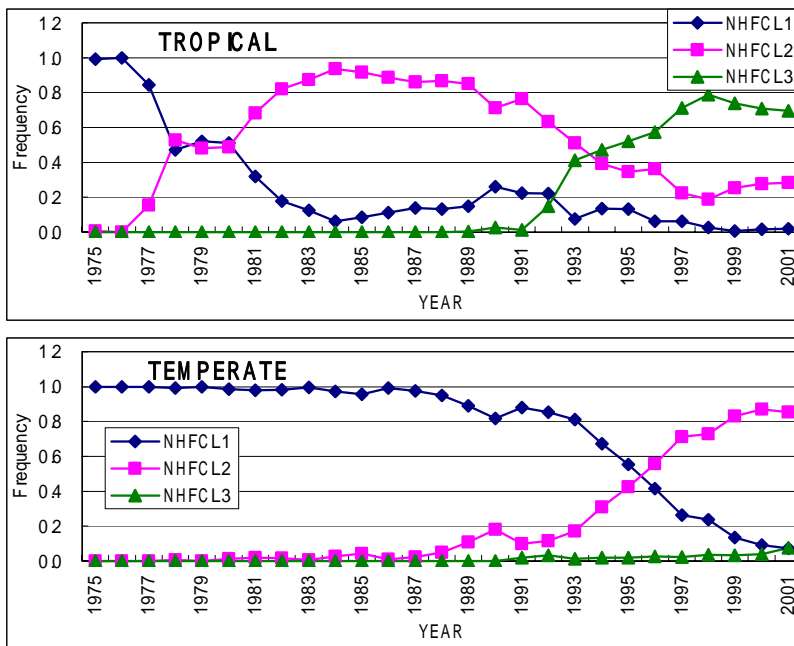


Fig. 2. Change in the frequency of NHF classified to three NHFCLs. NHFC L1 (NHF: 5-9, regular set), NHFC L2 (NHF: 10-15, deep set) and NHFC L3 (NHF:16-21, very deep set).

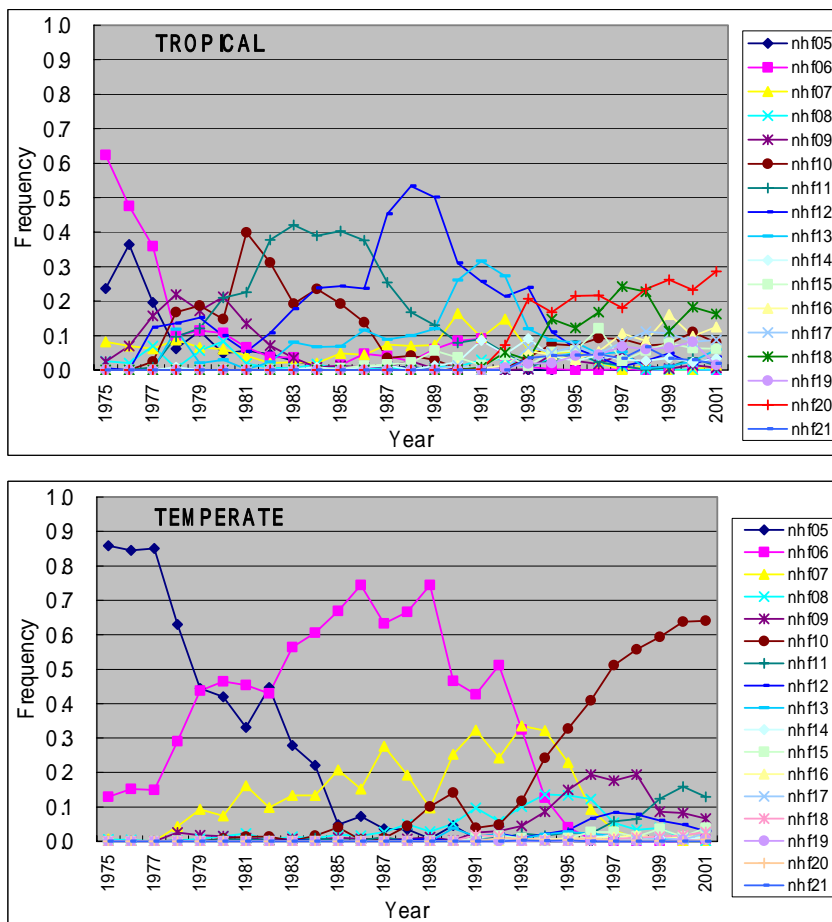


Fig. 3. Change in the frequency of each NHF used by Japanese longliners in the Indian Ocean from 1975-2001.

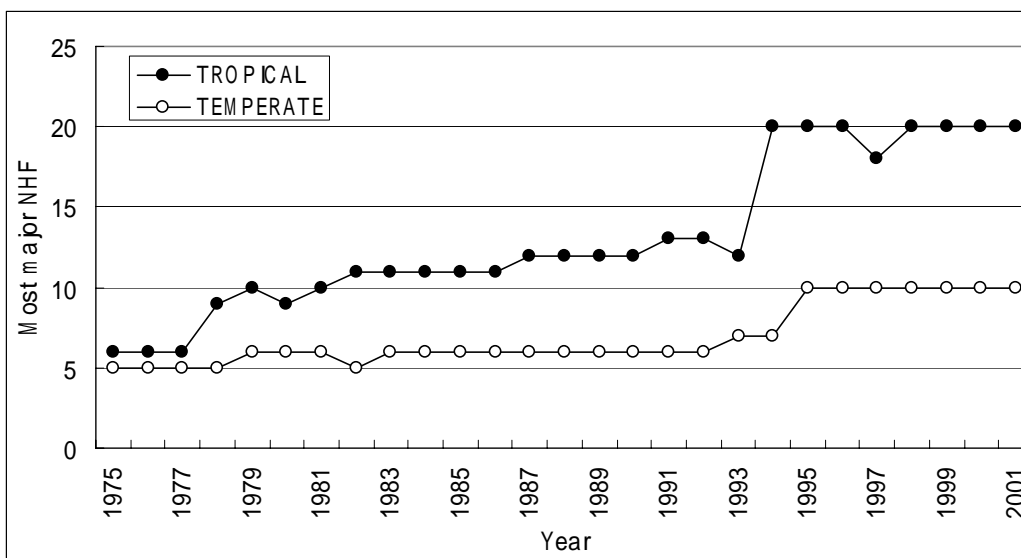


Fig. 4. Change in the most major NHF in Tropical and Temperate Areas.

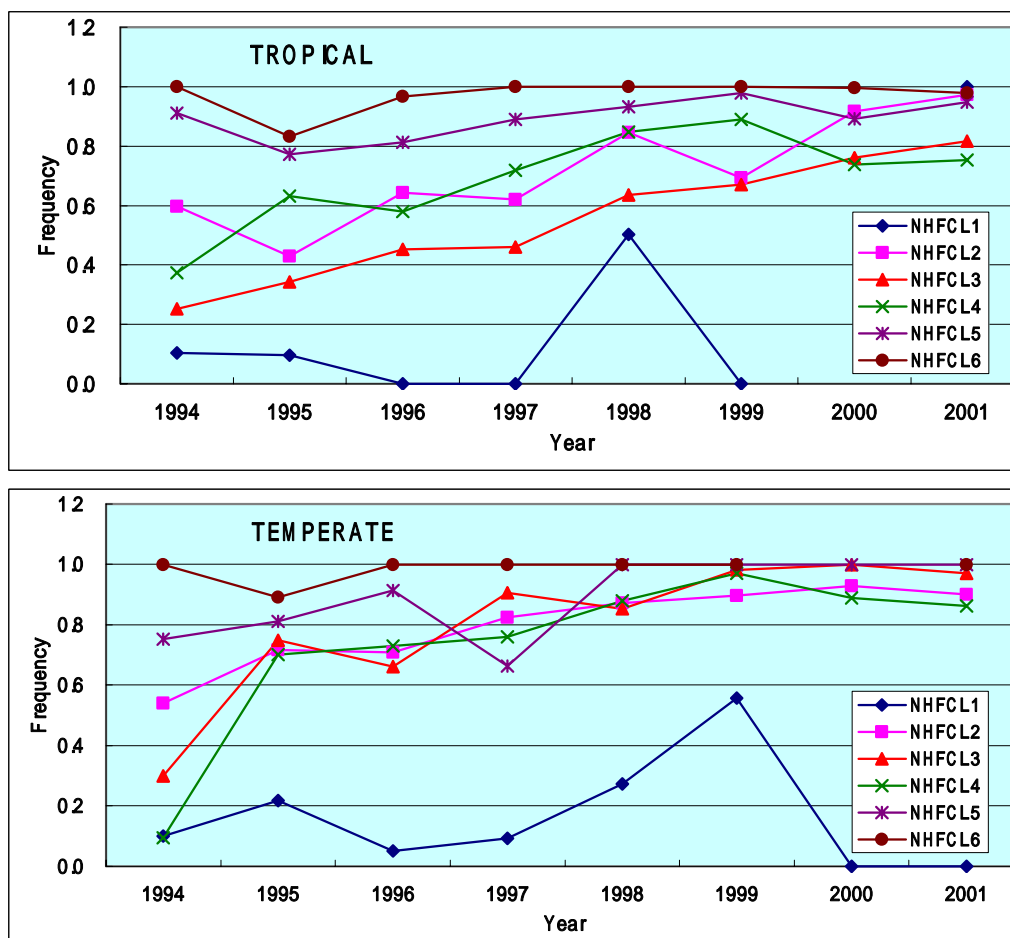


Fig. 5. Change in the frequency of Nylon mono-filament main line for each of six NHFCLs in the Tropical and Temperate Indian Ocean from 1994 to 2001.

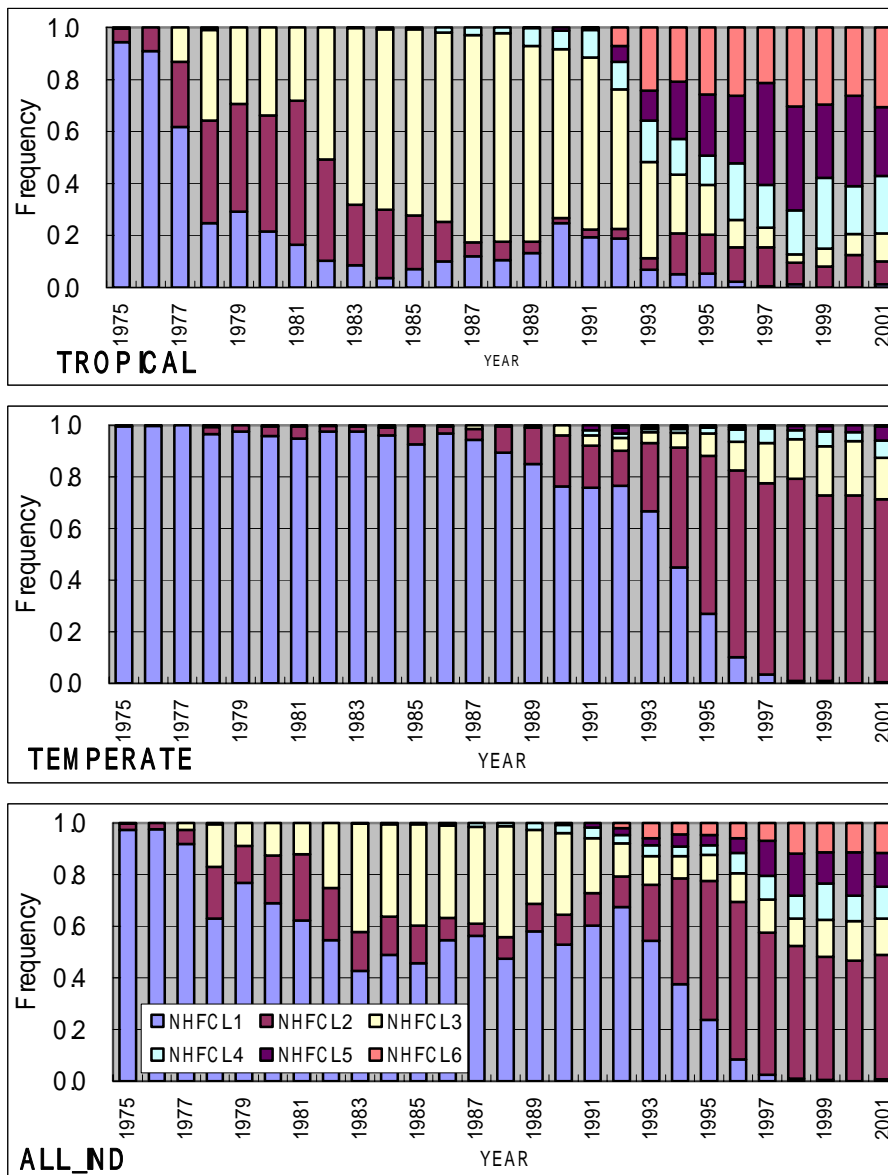
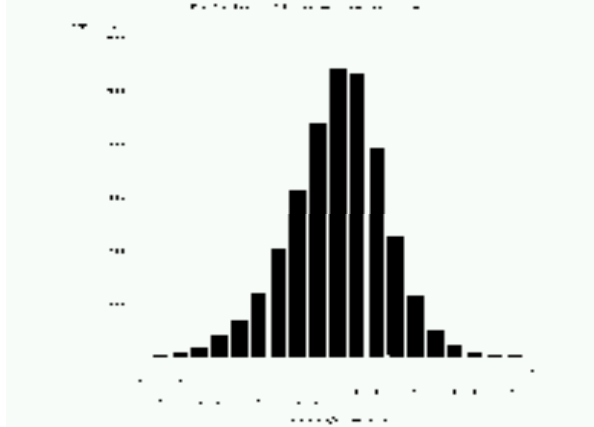
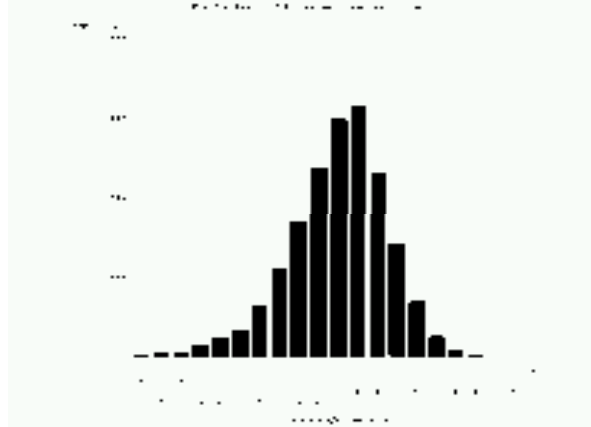


Fig. 6. Change in NHF divided into six classes (NHFL 1: 5-7, NHFL 2: 8-10, NHFL 3: 11-13, NHFL 4: 14-16, NHFL 5: 17-19, NHFL 6: 20-21) in each area from 1975 to 2001..

ALL ND



ALL TROPICAL



ALL TEMPERATE

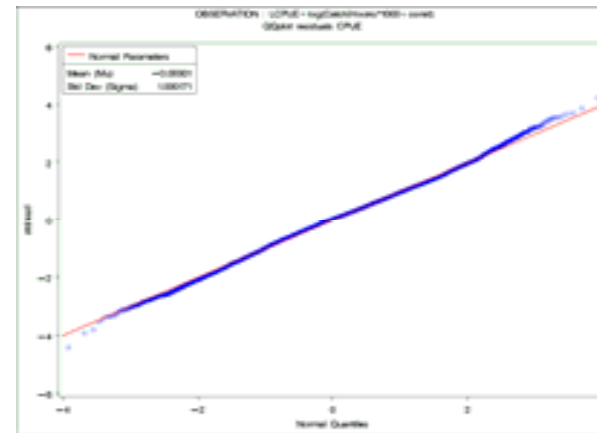
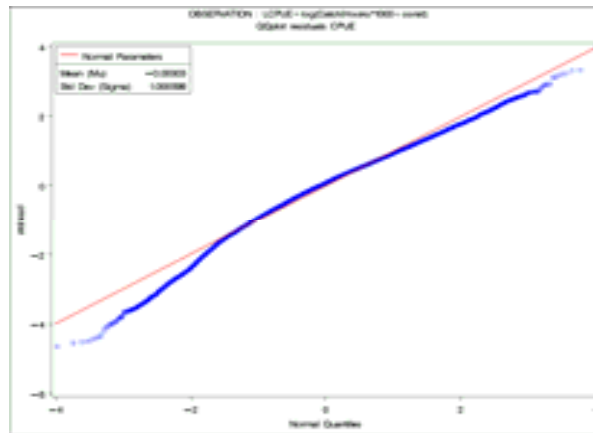
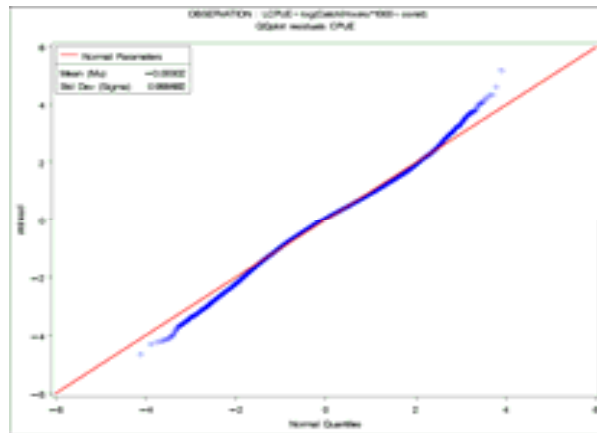
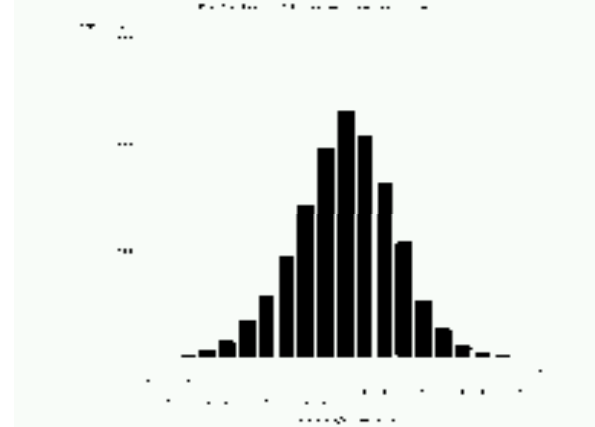


Fig. 7. Standardized residuals of year based standardization for each area expressed as histograms (upper figures) and QQ plots (bottom figures)..

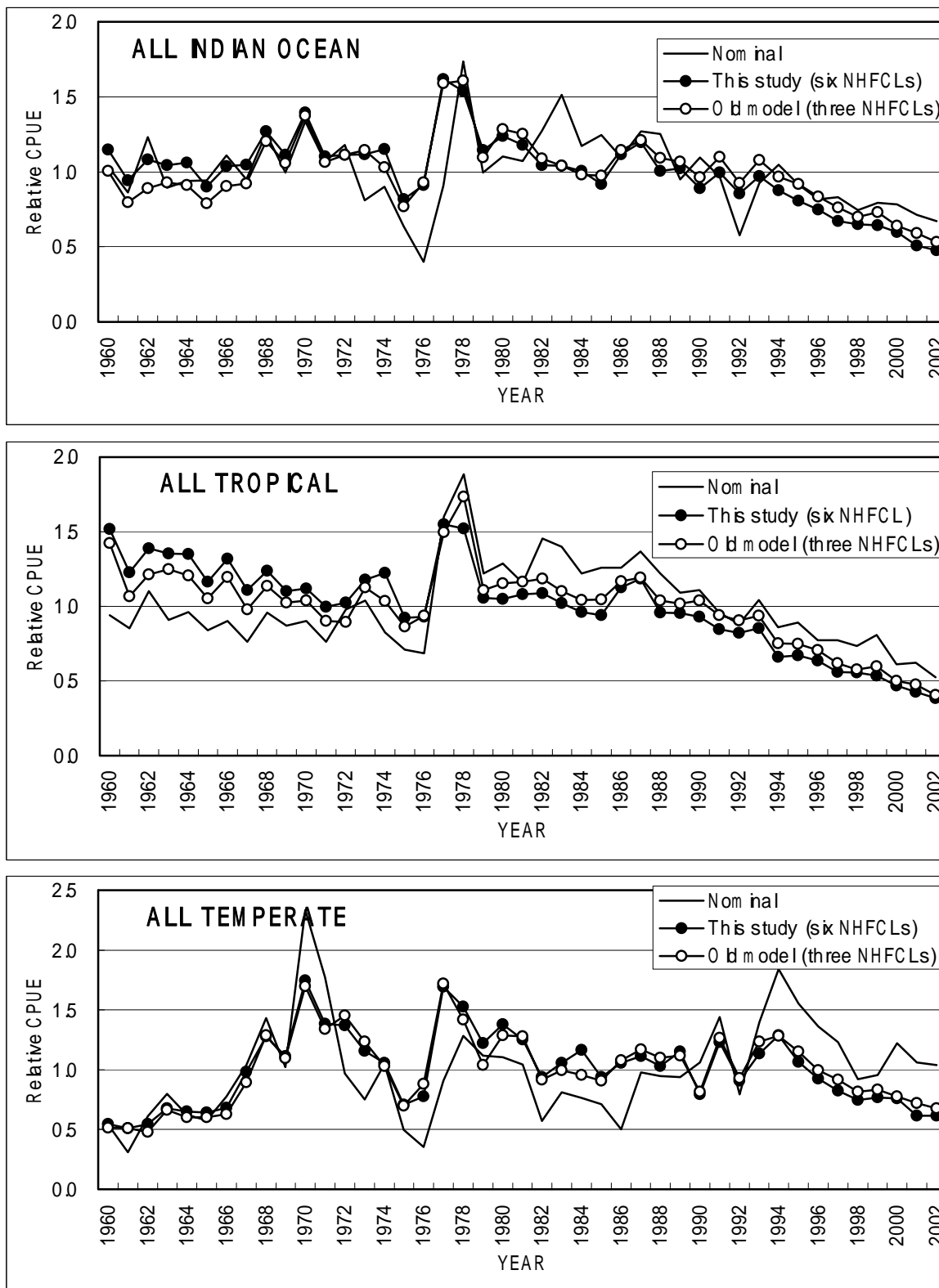


Fig. 8 Relative CPUEs for ALL Indian, Tropical and South areas derived from new model with six categories of NHFCL (solid circles) and old model with three categories of NHFCL (open circles) with Nominal CPUE.

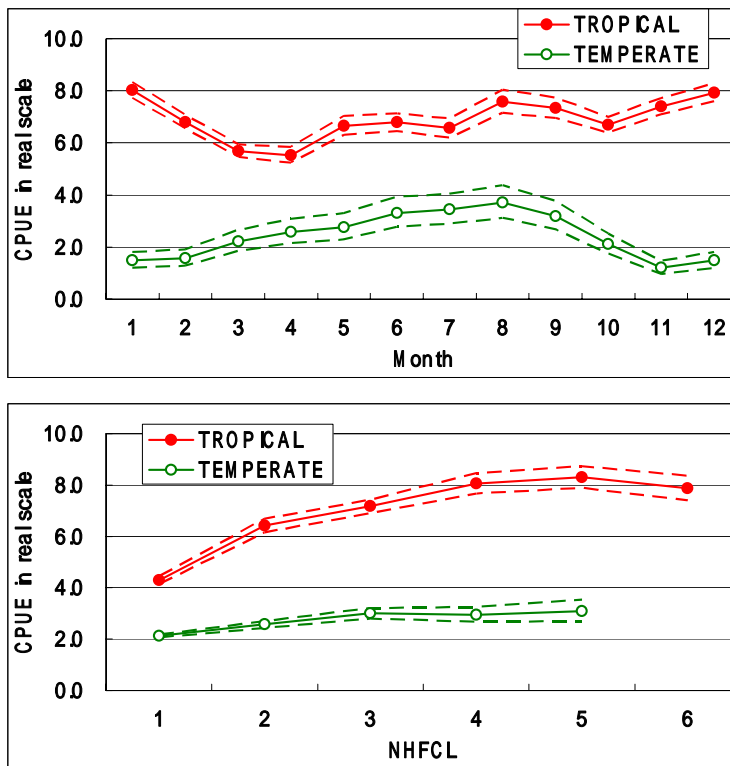


Fig. 9. Standardized CPUE for month and NHFCL expressed in real scale for Tropical and Temperate Indian Ocean. Unit of CPUE is catch in number per 1000 hooks.

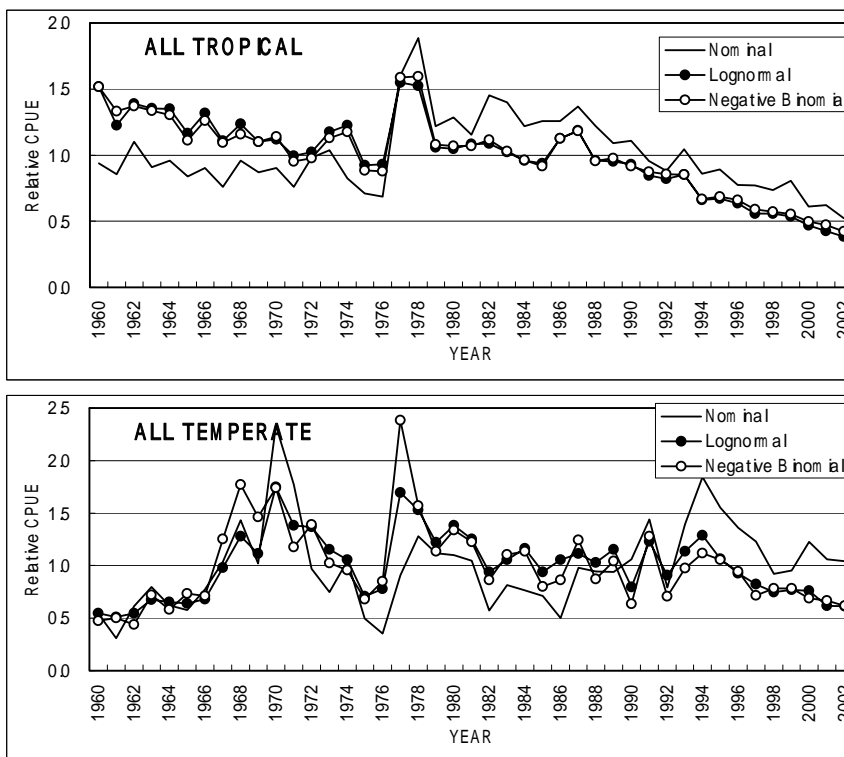


Fig. 10. Bigeye CPUE standardized by Catch-Negative Binomial model and CPUE- LogNormal model with Nominal CPUE.

Appendix Table Annual value of standardized Bigeye CPUE in All, Tropical and Temperate Indian Ocean from 1960-2002 expressed in relative scale in which the average from 1960 to 2002 is 1.0.

YEAR	ALL_IND	TROPICAL	TEMPERATE
1960	1.1474	1.5176	0.5441
1961	0.9427	1.2258	0.5097
1962	1.0822	1.3888	0.5464
1963	1.0425	1.3543	0.6774
1964	1.0601	1.3510	0.6522
1965	0.9013	1.1651	0.6412
1966	1.0356	1.3187	0.6810
1967	1.0461	1.1086	0.9797
1968	1.2704	1.2376	1.2774
1969	1.1124	1.1027	1.1124
1970	1.3935	1.1177	1.7472
1971	1.1033	0.9953	1.3810
1972	1.1128	1.0243	1.3702
1973	1.1160	1.1767	1.1554
1974	1.1503	1.2247	1.0542
1975	0.8174	0.9244	0.7056
1976	0.9125	0.9294	0.7783
1977	1.6188	1.5479	1.6943
1978	1.5372	1.5227	1.5273
1979	1.1429	1.0569	1.2198
1980	1.2374	1.0477	1.3802
1981	1.1798	1.0818	1.2503
1982	1.0419	1.0859	0.9380
1983	1.0395	1.0227	1.0574
1984	1.0046	0.9608	1.1636
1985	0.9193	0.9388	0.9399
1986	1.1180	1.1256	1.0544
1987	1.1954	1.1852	1.1121
1988	1.0042	0.9589	1.0275
1989	1.0243	0.9529	1.1530
1990	0.8904	0.9302	0.7946
1991	0.9948	0.8471	1.2292
1992	0.8545	0.8212	0.9064
1993	0.9715	0.8524	1.1345
1994	0.8775	0.6603	1.2887
1995	0.8085	0.6722	1.0629
1996	0.7464	0.6356	0.9248
1997	0.6699	0.5583	0.8246
1998	0.6519	0.5564	0.7455
1999	0.6441	0.5352	0.7676
2000	0.5984	0.4690	0.7605
2001	0.5066	0.4277	0.6165
2002	0.4758	0.3842	0.6132