UPDATED STANDARDIZED CPUE OF BIGEYE CAUGHT BY THE JAPANESE LONGLINE FISHERY IN THE INDIAN OCEAN

Okamoto, H., and N. Miyabe[1]

ABSTRACT

The catch per unit of effort (CPUE) of bigeye caught by the Japanese longline fishery in the Indian Ocean was standardized up to 1997 using general linear model (GLM) analysis. Standardized CPUE in the tropical area, which was relatively stable, ranged from 6 to 8 fish per 1,000 hooks in 1979-1987 and decreased continuously to about 4 in 1997. In contrast, CPUE in the southern area did not show the stable trend of the tropical areas, especially after 1990. This unstable CPUE pattern in the southern area in recent years seems to be derived mainly from the shift of targeting in longline operations. If the trend derived from analysis for 1952-1976 is included, current CPUE is estimated to be about 33 % of that in 1954.

RÉSUMÉ

Les captures par unité d'effort (PUE) des thons obèses pêchées par les palangriers japonais dans l'océan Indien ont été standardisées jusqu'à 1997 selon les méthodes d'analyse GLM (Modèle Linéaire Généralisé). Dans la zone tropicale, les PUE standardisées, qui étaient relativement stables, allant de 6 à 8 individus par 1.000 hameçons en 1979 jusqu'en 1987 et n'ont pas cessé de décliner pour arriver à environ 4 en 1997. Par contre, dans le sud, particulièrement après 1990, et comparativement au phénomène noté en eaux tropicales, on ne remarque aucune tendance stable au niveau des CPUE. Ce schéma d'instabilité des PUE dans le sud semble s'expliquer principalement par le fait que les palangriers ont ciblé d'autres espèces. Si les variations qui dérivent des analyses effectuées pour la période 1952–1976 sont prises en considération, on peut estimer que les PUE actuelles sont de l'ordre de 33 % de celles réalisées en 1954.

Introduction

Bigeye tuna is one of the *Thunnus* species distributed in both tropical and temperate waters. Juvenile and young fish often form schools, pure or mixed with other tunas, near the sea surface, where they are exploited by fisheries using surface gear such as purse seines. Adults, however, inhabit waters at or just beneath the thermocline, deeper than other tunas (Suda *et al*. 1969), and are mostly caught with longline gear.

Longline catch records indicate that bigeye tuna in the Indian Ocean are distributed north of 40°S (Figure 1). This area overlaps widely with that of yellowfin tuna in the tropical area, and partly with that of southern bluefin tuna in the temperate area south of 30°S. Therefore, longline effort is not necessary directed at bigeye tuna.

In the late 1970s there were some changes in the number of hooks between floats used in longline operations. Before 1977 most Japanese longline vessels used baskets with from five to eight hooks between floats (Table 1), but then nine to thirteen hooks between floats became common, accounting for up to about 50 % of sets in the early 1980s. This latter type of mount is called "deep longline", and derives from attempts to improve the CPUE of bigeye tuna by increasing the depth at which the hooks fish. The positive effects on catch rate for bigeye were confirmed (Suzuki *et al*. 1977, Koido 1985).

Because of this change, when CPUE is to be used as an abundance index, nominal CPUE needs to be adjusted for these effects. In this paper, CPUE were standardized up to 1997 using the general linear model (GLM) technique.

Materials and methods

Data used

Japanese longline catch and effort statistics up to 1997 were used (1997 data are preliminary). The data set from 1975 to 1994, aggregated by month, 5-degree square and number of hooks between floats (NHF), was used for the analysis. Although there are data from 1952 to 1974, they were not used because they do not include information on NHF.

Model configuration

The distribution of effort (in number of hooks) and CPUE for bigeye in the Indian Ocean are shown in Figure 1. On the basis of this distribution, the main fishing ground was divided into seven areas for analysis (Figure 1-C).

To include the effect of NHF in the model, the number of branchlines per basket was divided into 3 classes (Class 1: 5-9; Class 2: 10-15; Class 3: 16-21). This classification of NHF was determined by considering the values of the estimates of the NHF parameter derived from a preliminary GLM analysis using the model in which only main effects were included. First, a GLM analysis was done separately for several combinations of effects (Table 2) for the tropical fishing zone (Areas 1-5), and the final model was selected.

The final model used for GLM analysis (log normal error structure model) was the following:

$$\text{Log}\,(CPUE_{ijkl} + \text{const}) = \mu + Y_{(i)} + M_{(j)} + A_{(k)} + G_{(l)} + M*A_{(m..)} + A*G_{(n)} + e_{(ijkl....)}$$

where:

Log: natural logarithm,
CPUE: catch in number of bigeye per 1,000 hooks,
const: 10 % of overall mean of CPUE
μ: overall mean,
$Y_{(i)}$: effect of year,
$M_{(j)}$: effect of fishing season (month),
$A_{(k)}$: effect of area,
$G_{(l)}$: effect of gear type (NHF)
$M*A_{(m..)}$ M*A (j, k) : interaction term between fishing season and area,

[1] National Research Institute of Far Seas Fisheries, 5 chome 7-1, Orido, Shimizu, 424-8633, Japan

$A*G_{(n)}$ A*G (k, l) : interaction term between area and gear type,

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

In order to compare the CPUE trend among areas, the same analyses were done for several combinations of areas [western tropical area (Areas 1 and 3), eastern tropical area (Areas 2, 4 and 5), southern area (Areas 6 and 7), and all areas (1-7)] using the final model. Moreover, to compare with past trends in the bigeye resource, the same analysis was done using data from 1952-1976, although the effect of gear type was not included in the model because gear information was not available for the data before 1974.

Results

The final model and results of ANOVA for the tropical area (Areas 1-5) are shown in Table 2. R-square was about 0.196. In this analysis, area and NHF showed large effects (Table 3). The distribution of overall residuals from the final model (Figure 2) seems to be not far from a normal distribution, and to be acceptable. This is also seen in the residual distribution by year (Figure 9). The nominal and the standardized CPUEs derived from GLM analyses for the tropical area, with their upper and lower 95 % confidence limits, are shown in Figure 3. The standardized CPUE and nominal CPUE show similar trends. The standardized CPUE was relatively stable and flat, ranging from 6 to 8 bigeye per 1,000 hooks during 1979-1987 and then decreasing gradually to about 4 in 1997. The results of the same analysis done for the western tropical area (Areas 1 and 3) and the eastern tropical area (Areas 2, 4 and 5) separately are shown in Figure 4. Basically, similar trends and levels of standardized CPUE were observed in both areas.

The standardized CPUE in the southern area (Areas 6 and 7) did not show the same stable trend as in the tropical areas, especially after 1990 (Figure 5). It decreased from about 3.8 bigeye per 1,000 hooks in 1978 to 1.7 in 1987, and then increased again to 3.7 in 1991. After this peak in 1991, it dropped to 2.0 in 1992, increased to 3.6 in 1994, and thereafter decreased steadily to 2.0 in 1997. In contrast to the CPUE in the tropical area, which declined gradually from 1988, the CPUE in the southern area in the same period was higher than before 1988. The results of the analysis in which all areas (Areas 1-7) were used are shown in Figure 6. Standardized CPUE remained at the same level or decreased slightly from 1977 to 1997, with some fluctuations.

The analysis using data for 1952-1976 showed a moderately flat declining trend in relative CPUE from 1954 (CPUE = 8) to 1970 (CPUE = 4) (Figure 7).

Discussion

In the Indian Ocean, about 70-90 % of the bigeye (in number) were caught in the tropical area (Areas 1-5) until 1990, although the percentage was less in 1970 and 1971 (about 55 %). The percentage declined to 25-50 % thereafter, and increased to 50-70 % in the southern area (Areas 6 and 7). It is supposed that these changes indicate the occurrence of a shift in target species for longline operations in the southern area. An unrealistic and unstable trend of standardized CPUE in this area, particularly in recent years, might suggest that the effect of the rapid change in targeting could not be standardized sufficiently. Figure 8 shows histograms of NHF frequency aggregated by five- to seven-year periods in the tropical and southern areas, overlaid on nominal CPUE for each NHF. In the tropical area, the mode of the NHF coincides roughly with higher bigeye CPUE in all aggregated periods. This indicates that bigeye was the main target species in this area. In the southern area, the mode of the NHF occurred at 5 or 6, even though the CPUE of bigeye was low at these NHF, and the peak CPUE was located at NHF = 10 in this area. In the most recent years, however, two modes of NHF (NHF = 7 and 10) were observed in the southern area. This would suggest that a substantial part of the fishing operation shifted its target species to bigeye recently in this area. Therefore, it is considered more reasonable to study the trend of the bigeye resource by restricting the analysis to the tropical region.

Standardized CPUE in the tropical area showed a gradual decreasing trend after 1988. In the last five years the CPUE fell year by year. In the historical CPUE trend from 1975, the current CPUE is about 50 % of that in 1977. If the trend derived from the analysis for 1952-1976 is included, the current CPUE is about 33 % of that in 1954. Standardized CPUE in this study show a much quicker drop than Hsu and Chang (1993), who also standardized the Japanese longline CPUE but did not include gear type. This fact suggests that including information on gear (number of hooks between floats, NHF) in GLM analyses is very important.

References

Hsu, C. C. and H. C. Chang 1993. An ASPIC analysis of Indian bigeye tuna stock. IPTP/TWS/93/2/14 13 pp.

Koido, T. 1985. Comparison of fishing efficiency between regular and deep longline gears on bigeye and yellowfin tunas in the Indian Ocean. IPTP/TWS/85/25, 62-70.

Suda, A., S. Kume and T. Shiohama. 1969. An indicative note on a role of permanent thermoclines as a factor controlling the longline fishing ground for bigeye tuna. Bull. Far Seas Fish. Res. Lab., 1, 99-114.

Suzuki, Z., Y. Warashina and M. Kishida 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.

Table 1. Number of hooks (thousands) used in the analyzed area, by year and by the number of hooks between floats (BR)

Year	BR4	BR5	BR6	BR7	BR8	BR9	BR10	BR11	BR12	BR13	BR14	BR15	BR16	BR17	BR18	BR19	BR20	BR21
1975	692	17637	11110	1679	785	590	275	444	242	0	0	0	0	0	0	0	0	0
1976	419	13815	4883	575	150	335	9	144	63	0	0	0	0	0	0	0	0	0
1977	43	9933	3512	306	530	587	456	685	738	0	0	0	0	0	0	0	0	0
1978	35	8387	4999	1489	256	2960	3237	2426	2523	1681	98	42	0	0	0	0	0	0
1979	4	5421	5566	1515	408	1391	1902	1193	1218	296	0	0	0	0	0	0	0	0
1980	0	5776	6497	1604	959	2112	2336	2130	918	308	0	0	0	0	0	0	0	0
1981	19	6585	8767	3458	792	1945	5510	3236	739	41	0	0	0	0	0	0	0	0
1982	67	9772	9301	2497	224	1624	6647	7613	2261	470	0	0	0	0	0	0	0	0
1983	0	5531	10680	2917	458	1157	5541	11660	5068	2344	112	0	0	0	0	0	0	0
1984	28	5271	14077	3737	628	339	6395	9787	6047	1723	219	0	0	0	0	0	0	0
1985	19	1588	17618	6813	705	708	7298	12856	7789	2320	97	214	0	0	0	0	0	0
1986	0	2270	21516	5394	667	446	4051	9974	6608	3146	305	353	0	0	0	0	0	0
1987	0	1163	17358	8861	903	452	1174	6268	10552	2204	304	418	0	0	0	0	0	0
1988	0	897	12628	4840	998	701	1781	3703	11410	2177	44	543	0	0	0	0	0	0
1989	0	173	15483	2932	729	303	2468	1714	6453	1543	166	716	0	27	0	0	0	0
1990	0	738	8600	6333	997	136	2394	1179	4362	4301	353	531	128	188	26	0	0	0
1991	0	329	11890	9205	2840	697	957	1304	2964	3647	1232	402	113	63	451	0	31	0
1992	7	409	15949	8391	2023	932	1581	593	1993	2001	306	784	83	258	726	36	781	0
1993	0	211	9695	10433	3090	1449	3919	839	2228	1294	929	393	473	705	321	153	1876	346
1994	4	49	5918	15395	6930	4803	11952	1196	2406	1614	948	784	765	496	1845	351	2081	524
1995	4	32	2606	14690	8925	9286	20813	2313	2952	2672	634	1152	868	972	1647	585	2766	597
1996	0	0	469	6441	8216	12660	26548	1920	4746	2493	1463	3585	1469	1082	2922	786	4174	801
1997	0	1	189	1236	2573	7732	21260	3286	3762	1508	1486	1849	2617	2055	4961	1726	4058	739

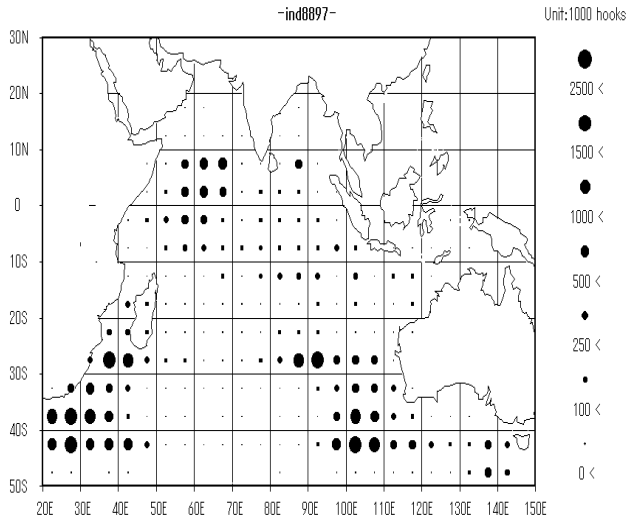
Table 2. Result of ANOVA from the general linear model for bigeye in the tropical area (Areas 1-5) in the Indian Ocean, 1975-1997.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F value	Pr > F	R^2
YR + MN + AREA						
Model	37	1190.70	32.18	63.36	0.0001	0.1397
Error	14435	7331.08	0.51			
Total	14472	8521.78				
YR + MN + AREA + MN*AREA						
Model	81	1357.81	16.76	33.67	0.0001	0.1593
Error	14391	7163.97	0.50			
Total	14472	8521.78				
YR + MN + AREA + NHFCL						
Model	39	1413.25	36.24	73.86	0.0001	0.1664
Error	14433	7080.80	0.49			
Total	14472	8494.05				
YR + MN + AREA + NHFCL + MN*AREA + AREA*NHFCL						
Model	91	1673.61	18.39	38.62	0.0001	0.1964
Error	14381	6848.17	0.48			
Total	14472	8521.78				

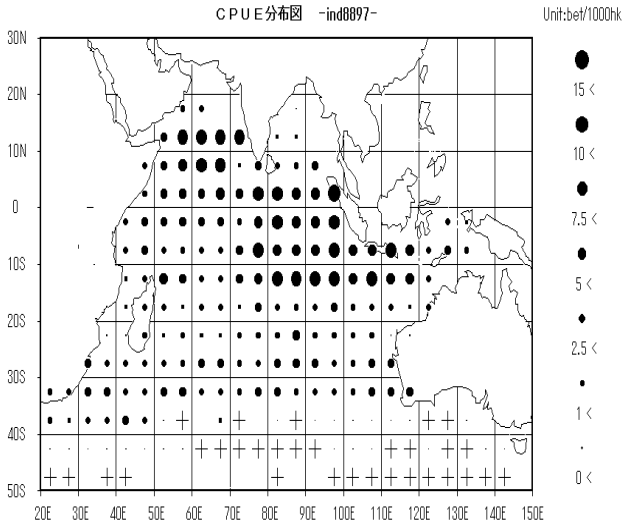
Table 3. Result of F-test of each effect term in GLM of finally cited model (YR+MN+AREA+NHFCL+MN*AREA+AREA*NHFCL).

Source	Degrees of freedom	Sum of squares	Mean square square	F Value	Pr > F
YEAR	22	452.24	20.56	43.17	0.0001
MONTH	11	50.34	4.58	9.61	0.0001
AREA	4	235.44	58.86	123.61	0.0001
NHF	2	168.40	84.20	176.81	0.0001
MN*AREA	44	176.34	4.01	8.42	0.0001
AREA*NHFCL	8	87.60	10.95	23.00	0.0001

A



B



C

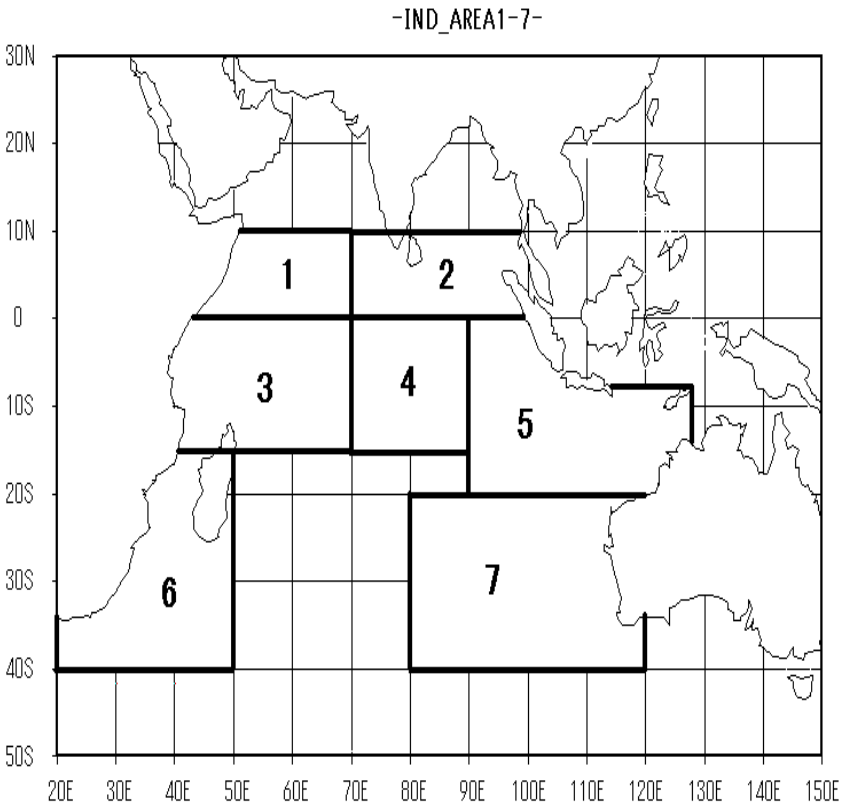


Figure 1. Geographic distribution of Japanese longline effort (1000 hooks, A) and CPUE for bigeye (B) in the Indian Ocean, 1988-1997. C is the Area definition used in this analysis.

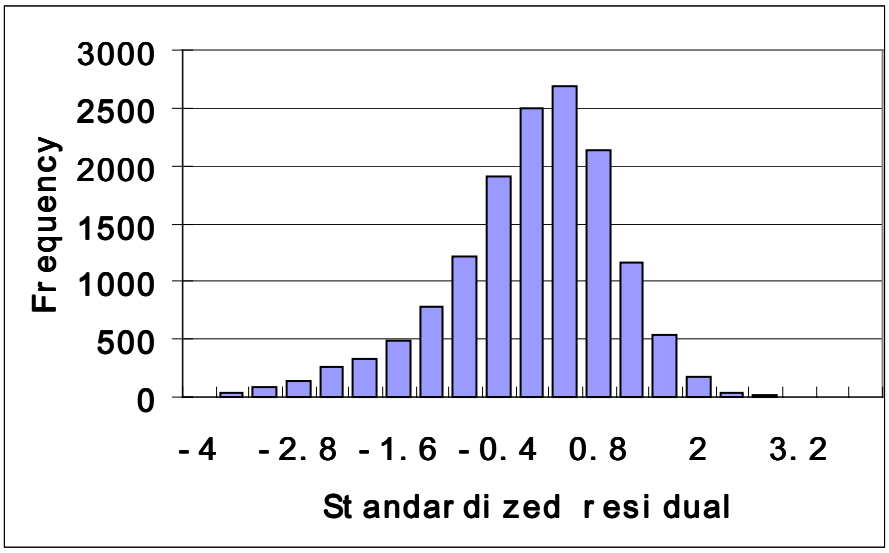


Figure 2. Overall histogram of standardized residuals from GLM analysis for tropical area (area 1-5).

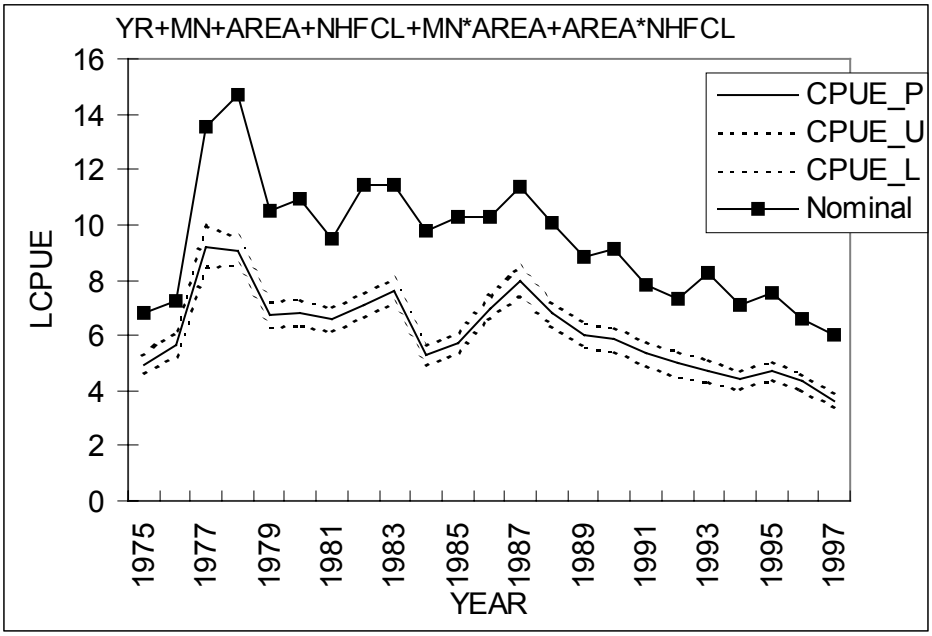


Figure 3. Annual change of relative CPUE (upper and lower broken lines indicate 95 % confidence limits) in the tropical area (area 1-5), and nominal CPUE (solid line with square mark).

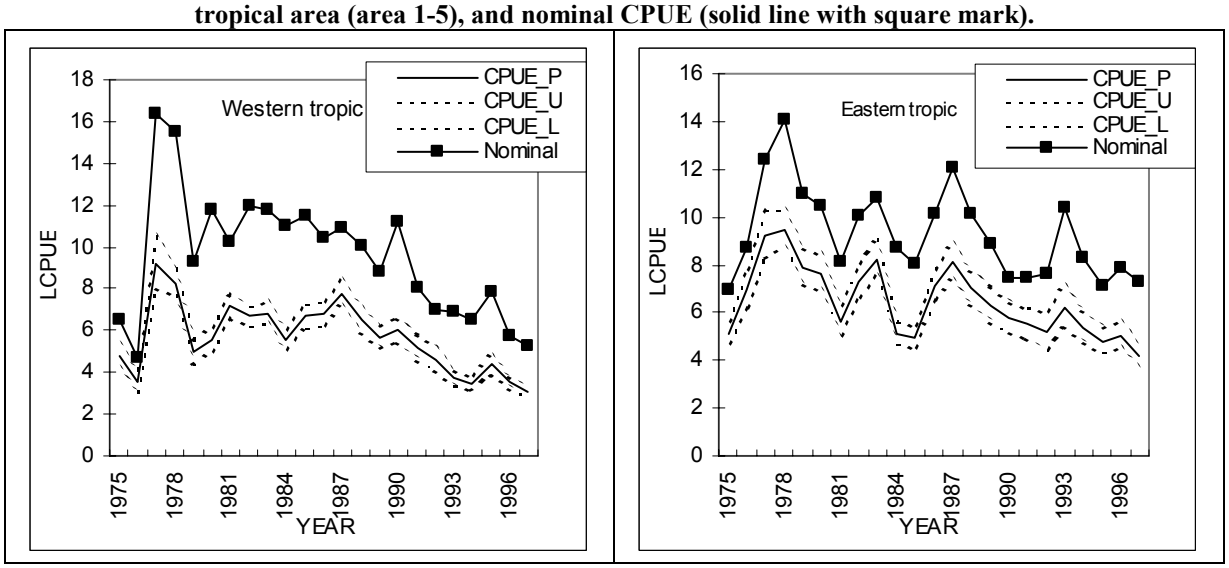


Figure 4. Relative CPUE and nominal CPUE of western (area 1 & 3, left) and eastern (area 2,4&5, right) areas.

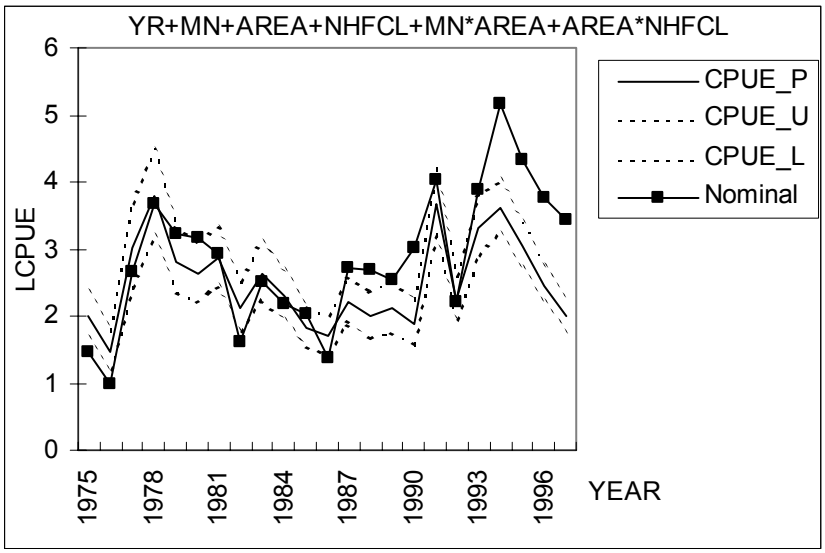


Figure 5. Relative CPUE and nominal CPUE of south area (area 6 & 7).

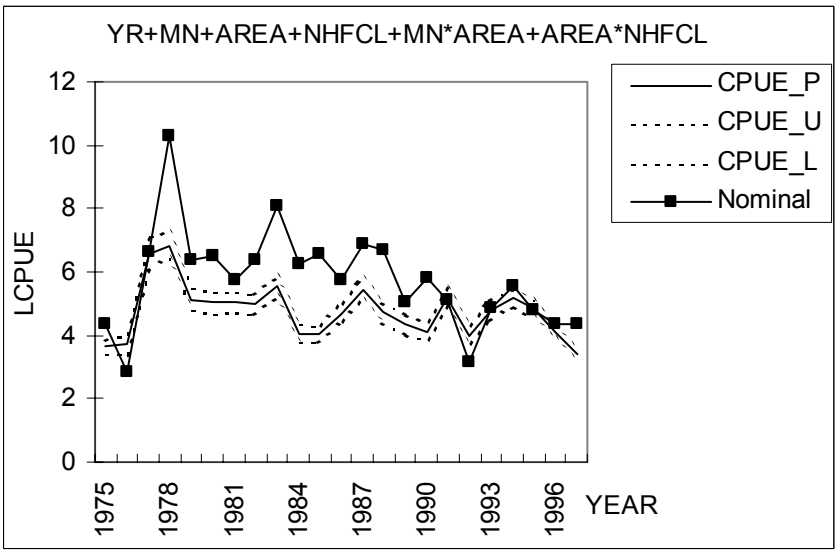


Figure 6. Relative CPUE and nominal CPUE of all area (area 1-7).

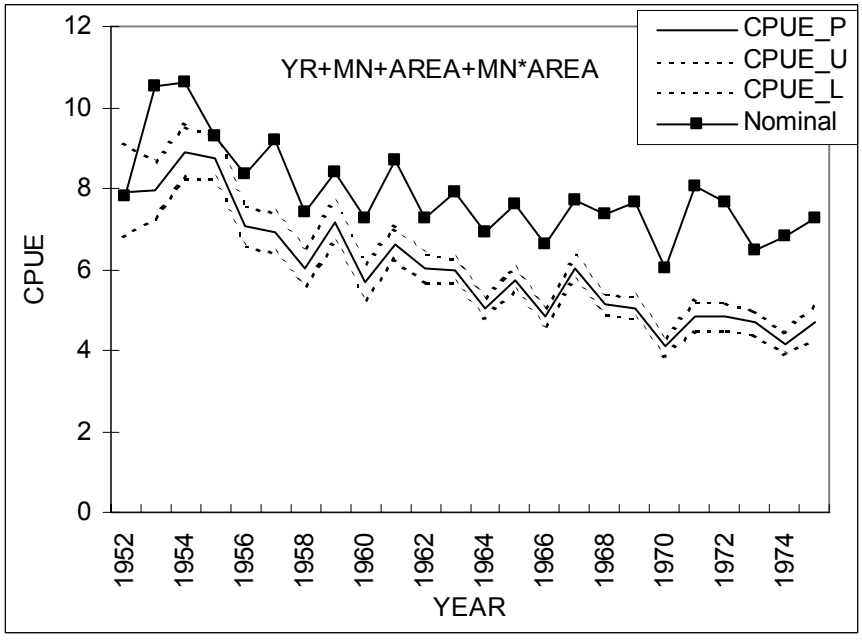


Figure 7. Relative CPUE and nominal CPUE of tropical area (area 1-5) in 1952 through 1976.

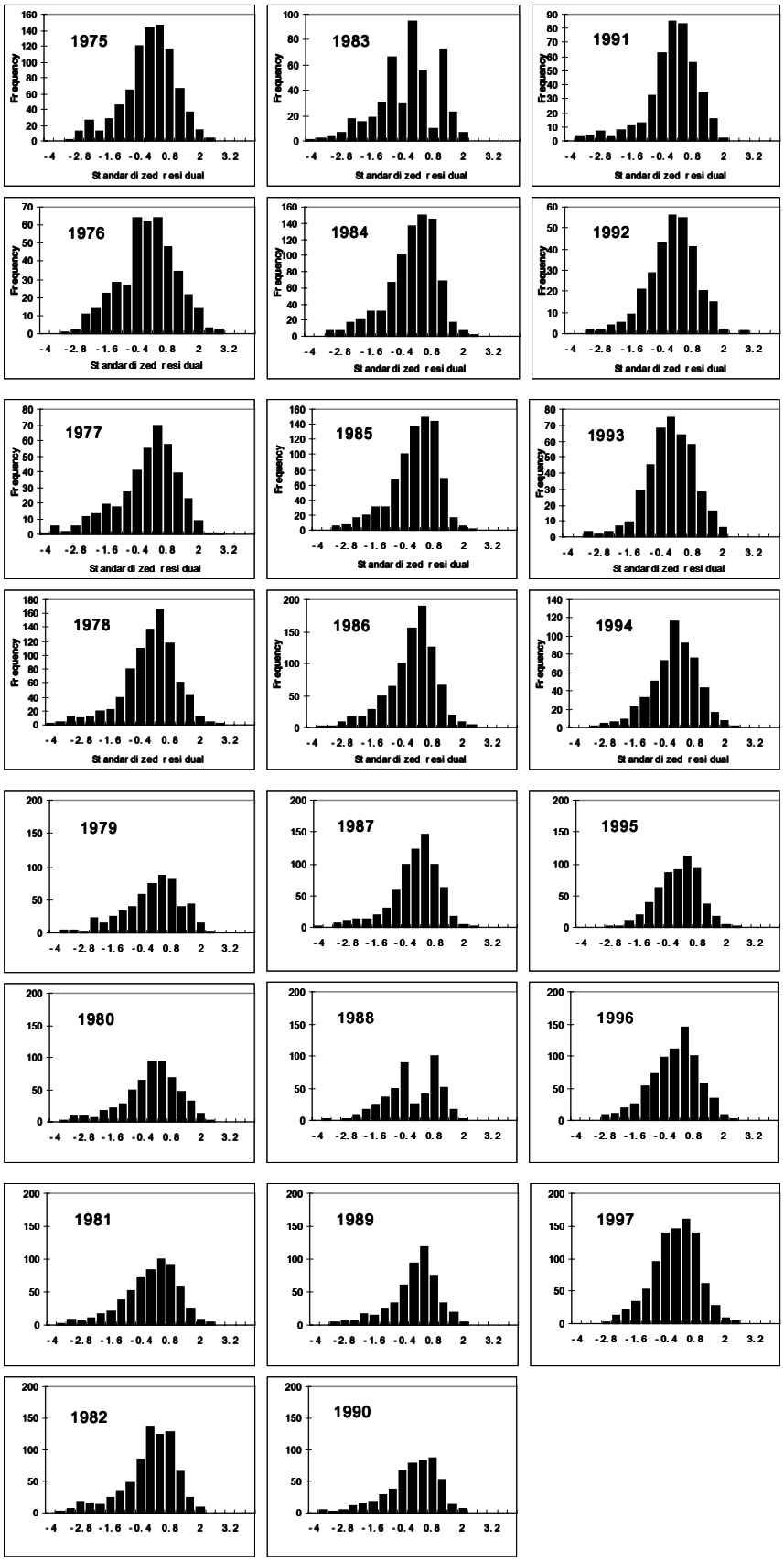


Figure 8: Histograms of standardized residuals of GLM analysis for tropical area for each year.