Col.Vol.Sci.Pap. ICCAT, 48 (1) : 249-254 (1998)

# STANDARDIZATION OF CPUE FOR SAILFISH AND SPEARFISH CAUGHT BY THE JAPANESE LONGLINE FISHERY IN THE ATLANTIC OCEAN

*Yokawa, K.*[1], *Y. Uozumi*[1]


## SUMMARY

Species combined CPUE for sailfish and spearfish caught by the Japanese longline fishery was updated and time series of CPUE for sailfish was estimated based on the information of recent catch distribution of sailfish and spearfish. The obtained annual indices of abundance indicated that the stock status of sailfish and spearfish were in a historically low level in both the east and the west Atlantic.

## RÉSUMÉ

La CPUE d'espèces combinées pour l'espadon et le makaire bécune-marlin de Méditerranée pris par la pêcherie palangrière japonaise a été actualisée et la série temporelle de CPUE du voilier a été estimée sur le fondement de l'information sur la distribution de la prise récente de voilier et de makaire bécune-marlin de Méditerranée. Les indices annuels d'abondance obtenus ont indiqués que les stocks de voilier et de makaire bécune-marlin de Méditerranée se trouvaient à un niveau historiquement bas, dans l'Atlantique Est comme dans l'Atlantique Ouest.

## RESUMEN

Se actualizó la CPUE de especies combinadas para pez vela y *Tetrapturus pfluegeri* capturado por la pesquería de palangre japonesa y se estimó la serie temporal de CPUE para pez vela, basándose en la información sobre la distribución de la captura reciente de pez vela y *Tetrapturus pfluegeri*. Los índices de abundancia anuales obtenidos indicaban que los stocks de pez vela y de *Tetrapturus pfluegeri* se encontraban en un nivel bajo histórico, tanto en el este como en el oeste del Atlántico.


### Introduction

Uozumi (1994) calculated the sailfish and spearfish combined CPUE of the Japanese longline fishery for the east and west Atlantic with General linear Model for the purpose of stock assessment use. In 1993, the new catch reporting system which records the catch of sailfish and spearfish separately was introduced in the Japanese longline fishery. Uozumi (1997) analyzed distributions of sailfish and spearfish during 1994 to 1996 by using data from the new catch reporting system. In the present study, species combined CPUE of the Japanese longline fishery was updated, and also species separate CPUE were tried to be estimated for sailfish by using the results of Uozumi (1997)

### Materials and methods

A. Update of the species combined CPUE

The basic data for this study were obtained from the Japanese longline fishery statistics compiled at the National Research Institute of Far Seas Fisheries for 1961-1996. Two kinds of databases were used. The Database-I has the same format as ICCAT TASK-II with catch of sailfish and spearfish combined while the new Database-II, from 1975 when Japanese deep longline fishery started in the Pacific, contains additional information for the gear configuration, i.e. the number of branch lines between floats.

CPUE was calculated as catch number per 1,000 hooks. Observation with

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

less than 5,000 hooks per month and per 5x5 blocks were excluded from analysis. Database-I from 1961 to 1975 and II from 1975 to 1996 were used for the GLM standardization and standardized CPUE of these two Databases were combined into a series of scaled annual abundance indices.

B. Selection of the model

Selection of the factors included in the model as main effects were followed by Uozumi (1994) except for CPUEs of other species which were excluded from main effects in the present study as consistent trends were observed in them. Same subareas as Uozumi (1994) were used for the east and the west Atlantic.

The multiplicative model was selected. For Database-I is:

$$\ln(CPUE_{ijk}+const)=\ln(\mu)+\ln(YR_i)+\ln(QT_j)+\ln(AR_k)+\ln(INTER)+\varepsilon$$

and for Database-II is:

$$\ln(CPUE_{ijkl}+const)=\ln(\mu)+\ln(YR_i)+\ln(QT_j)+\ln(AR_k)+\ln(GE_l)+\ln(INTER)+\varepsilon_{ijkl}$$

where ln: natural logarithm, $CPUE_{ijk}$: nominal CPUE (catch in number per 1,000 hooks, in year i, quarter j, area k), const: 1/10 of overall mean, $\mu$ : overall mean, $YR_i$: effect of year i, $QT_j$: effect of quarter j, $AR_k$: effect of area k, $GE_l$: effect of gear l, INTER: any combination of two way interaction, and $\varepsilon$ : normal error term. Analysis was made though the GLM procedure of computer software, "SAS Ver. 6.11".

C. Estimation of sailfish CPUE

Along with the new catch reporting system which reports the separate catch of sailfish and spearfish was introduced in 1993. The catch distributions by the two species were analyzed by Uozumi (1994, 1997). The results of these two reports were well in accordance with the result of Kikawa and Honnma (1982) which estimated the partition of sailfish and spearfish of the Japanese commercial catch during 1956 to 1980 (two species combined) by extrapolating the survey data in the period of 1957 to 1970 (two species separated).

From this consistent feature of the mixture rate of sailfish and spearfish in 5x5 blocks, it was assumed that its mixture rate remained more or less constant in period between 1960's and mid 1990's though the level of abundance of these two species changed in this period. In the present study, a trend of CPUE of sailfish was estimated by extracting the data of 5x5 blocks from Database I and II in which above 95% sailfish ratio in the total of sailfish and spearfish catches was observed in the period of 1994 to 1996 (Uozumi, 1997). To introduce the effect of area into the model, the designated blocks were divided into two areas at the equator. Because of small number of data, the sailfish CPUE in the west subarea were not estimated in this study.

Estimation of the spearfish CPUE could not be done in this study as there was no 5x5 blocks which observed higher than 95% spearfish catch ratio during 1994 to 1996 (Uozumi, 1997).

## Results

A. Update of species combined CPUE

Table 1 shows the results of Akaike's Information Criteria (AIC) calculation by the east and the west Atlantic and by Database under various conditions of main effects and two way interactions. The model with main effects and two way interactions which produced the lowest value of AIC were selected as an appropriate model in each area and database.

Tables 2-5 show the results of analysis of variance which reveal that all main effects and interactions were significant at significant level of 0.01% for each Database in the east and the west Atlantic, except for QT in the east Atlantic for Database-I. The overall histograms of standardized residuals for the four cases were closely resemble to normal distributions, though the skewed distributions was observed in the Database-II in the west Atlantic (Fig. 1). R-square values ranged from 0.25 to 0.37 except for Database-II in the east Atlantic that was less than half of the others (0.12).

The scaled annual abundance indices (proportioned to the value of 1975 set as 1.0) with lower and upper 95% confidence limits were shown in Fig. 2 for both of the east and the west Atlantic.

In the east Atlantic, abundance indices showed increasing tendency from 1961 to 1968 with some fluctuations which followed by sharp decline from 1968 to 1971. Since 1971, indices demonstrated steady decreasing trend until the recent years and the average value of indices in 1990's was 3% of that in 1970's. In the west Atlantic, abundance indices demonstrated two peaks in 1968 and 1974. During 1974 to 1977, it showed sharp decreasing which followed by gradual but steady decreasing trend until 1996. The average value of indices in 1990's was 13% of that in 1970's.

B. Estimation of sailfish CPUE

The selection of main effects and interaction terms for the model was done by the calculation of AIC (Table 6) for both of two Databases. As a result of variance analysis, almost all main effects and all interactions were revealed to be significant at the level of 0.01% (Table 7). The distribution of residuals in Database-I could be resembled to normal distributions, though the skewed distributions was observed in the Database-II (Fig. 3). The values of R-square were 0.40 for Database-I and 0.13 for

Database-II.

The scaled annual abundance indices suggested the existence of two phases in the trend of estimated sailfish abundance during the period of analysis (Fig. 4). Former phase was between the 1960's and early 1970's whose abundance level was relatively high with large fluctuations. Later phase starting from 1980 was characterized by relatively low level of abundance and showed steady downward trend. The value of indices of 1990's was about one seventh of that in the first half of 1980's.

## Discussions

In this study, CPUEs of other species, which was taken into account in the model used by Uozumi (1994), were not included as the main effects for the model. This change in the model brought the significant contrast of the trend of species combined abundance indices in the east Atlantic between the results of Uozumi (1994) and the present study. In the results of Uozumi (1994), the values of abundance indices in the 1960's were about 2-3 times higher than those in period of after 1975 while values in former period were about 10 times higher than those in later period in this study. In the west Atlantic, a time series trend of abundance indices for sailfish and spearfish in this study were quite similar to that in Uozumi (1994).

Estimated annual abundance indices for sailfish in the east Atlantic showed a sharp decreasing in the period of 1968 to 1976 as it was also the case in the species combined indices though decline was not so dramatic as that in species combined indices. The sudden increase of the indices observed in 1978 may not reflect the true trend of this stock as it was only one year of event. One of the main reasons of this unrealistic spike could be attributed to the difference between the effort distribution of Japanese longliners and habitat of sailfish and spearfish. Uozumi (1997) indicated that sailfish and spearfish were concentrated in the area between 10° N and 10° S in the east Atlantic where relatively low fishing efforts of Japanese longliners had been made since 1970's (ICCAT, 1994). The Japanese longliners have targeted bigeye, bluefin and southern bluefin tunas since 1970's. The area separation used in this study would not be able to eliminate the effects of this difference from the model. Farther investigation about the way of appropriate area separation should be necessary.

In the present study, three abundance indices were obtained. It should be noted that the application of these indices should be treated with care as these indices were affected by changes of target species of Japanese longliners as well as the yearly and spatial change in the species compositions. Although the standardized CPUEs of Japanese longliners indicate that the statuses of stocks of sailfish and spearfish in the Atlantic Ocean were at low level since late 1970's, this period was coincide with the period of the ratio of the combined sailfish and spearfish catch of Japanese longliners to the total dropped to lower than 10% in the Atlantic (Uozumi, 1996). The CPUEs derived from such a low coverage of catch might not reflect the true situation of the stock. The comparison with other indices such as CPUEs of coastal fishery should be necessary to see the condition of the sotck.

## References


ICCAT 1992: Report of the second ICCAT billfish workshop. *ICCAT Coll. Vol. Sci. Pap.* XLI 587pp.

Kikawa, S and N. Honma 1982: Trends in the Japanese sailfish/longbill spearfish catches in the Atlantic Ocean as apportioned into separate species. *ICCAT Coll. Vol. Sci. Pap.* XVIII (3), 645-649.

Uozumi, Y. 1994: Standardization of species combined CPUE for sailfish and Sperafish caught by Japanese longline fishery in the Atlantic Ocean. *SCRS/94/155.* 8pp.

Uozumi, Y. 1995: Preliminary analysis on the distribution of sailfish and longbill spearfish in the Atlantic Ocean in 1993 based on the logbook data. *ICCAT Coll. Vol. Sci. Pap.* XLIV (3), 26-29.

Uozumi, Y. 1996: Recent status of the Japanese longline fishery in the Atlantic Ocean laying stress on billfish catches. *SCRS/96/95,* 12pp.

Uozumi, Y. 1997: Distribution of sailfish and longbill spearfish in the Atlantic Ocean during 1994-1996 based on the logbook database of the Japanese longline fishery. *Document submitted to this meeting.*

Table 1. Calculation of AIC for the models of species combined CPUE standardization. First three columns indicate combinations of two way interaction introduced into the model.

The west Atlantic (Database-II, 1975-1996)

| 1st | 2nd | 3rd | No. of ob. | MSE | ln(MSE) | No. par. | AIC | Rank |
|---|---|---|---|---|---|---|---|---|
| area*qt | | | 8144 | 1.496 | 0.403 | 55 | 3391.94 | 5 |
| gear*qt | | | 8144 | 1.516 | 0.416 | 51 | 3490.33 | 7 |
| area*gear | | | 8144 | 1.504 | 0.408 | 55 | 3433.43 | 6 |
| qt*area | qt*gear | | 8144 | 1.481 | 0.393 | 71 | 3342.34 | 3 |
| qt*area | area*gear | | 8144 | 1.468 | 0.384 | 75 | 3274.21 | 2 |
| gear*qt | gear*area | | 8144 | 1.483 | 0.394 | 71 | 3350.75 | 4 |
| area*qt | gear*qt | area*gear | 8144 | 1.452 | 0.373 | 91 | 3217.71 | 1 |

The east Atlantic (Database-II, 1975-1996)

| 1st | 2nd | 3rd | No. of ob. | MSE | ln(MSE) | No. Par. | AIC | Rank |
|---|---|---|---|---|---|---|---|---|
| area*qt | | | 14462 | 5.039 | 1.617 | 50 | 23488.67 | 6 |
| gear*qt | | | 14462 | 5.038 | 1.617 | 50 | 23486.46 | 5 |
| area*gear | | | 14462 | 5.041 | 1.618 | 50 | 23494.27 | 7 |
| qt*area | qt*gear | | 14462 | 5.022 | 1.614 | 66 | 23471.15 | 3 |
| qt*area | area*gear | | 14462 | 5.026 | 1.615 | 66 | 23483.17 | 4 |
| gear*qt | gear*area | | 14462 | 5.021 | 1.614 | 66 | 23467.86 | 2 |
| area*qt | gear*qt | area*gear | 14462 | 5.008 | 1.611 | 82 | 23464.10 | 1 |

The west Atlantic (Database-I, 1961-1975)

| 1st | 2nd | 3rd | No. of ob. | MSE | ln(MSE) | No. Par. | AIC | Rank |
|---|---|---|---|---|---|---|---|---|
| area*qt | | | 4478 | 1.442 | 0.366 | 49 | 1737.19 | 1 |
| no two way interactions | | | 4478 | 1.523 | 0.420 | 29 | 1940.83 | 2 |

The east Atlantic (Database-I, 1961-1975)

| 1st | 2nd | 3rd | No. of ob. | MSE | ln(MSE) | No. Par. | AIC | Rank |
|---|---|---|---|---|---|---|---|---|
| area*qt | | | 3039 | 0.245 | -1.406 | 43 | -4187.65 | 1 |
| no two way interactions | | | 3039 | 1.252 | 0.225 | 27 | 737.60 | 2 |

Abbreviations: No. of ob., Number of observations; MSE, mean square error; No. par., number of parameter; AIC, Akaike's Information Criterion

Table 2. Analysis of variance for Database-I in the east Atlantic from 1961-1975. R-square=0.37. CV=-104.3.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 29 | 1895.107708 | 65.348542 | 56.23 | 0.0001 |
| Error | 2722 | 3163.413374 | 1.162165 | | |
| Corrected Total | 2751 | 5058.521082 | | | |

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YR | 14 | 476.462128 | 34.033009 | 29.28 | 0.0001 |
| QT | 3 | 0.620714 | 0.206905 | 0.18 | 0.9113 |
| AREA | 3 | 447.387326 | 149.129109 | 128.32 | 0.0001 |
| QT*AREA | 9 | 152.145826 | 16.905092 | 14.55 | 0.0001 |

Table 3. Analysis of variance for Database-II in the east Atlantic from 1975-1996. R-square=0.12. CV=-63.7.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 57 | 9474.161894 | 166.213367 | 33.19 | 0.0001 |
| Error | 14404 | 72141.637358 | 5.008445 | | |
| Corrected Total | 14461 | 81615.799251 | | | |

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YR | 21 | 3880.697972 | 184.795142 | 36.90 | 0.0001 |
| QT | 3 | 113.353214 | 37.784405 | 7.54 | 0.0001 |
| AREA | 3 | 1664.033604 | 554.677868 | 110.75 | 0.0001 |
| GEAR | 3 | 268.190340 | 89.396780 | 17.85 | 0.0001 |
| QT*GEAR | 9 | 300.452907 | 33.383656 | 6.67 | 0.0001 |
| AREA*GEAR | 9 | 240.271626 | 26.696847 | 5.33 | 0.0001 |
| QT*AREA | 9 | 223.825140 | 24.869460 | 4.97 | 0.0001 |

Table 4. Analysis of variance for Database-I in the west Atlantic from 1961-1975. R-square=0.27. CV=-168.6.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 33 | 2127.910170 | 64.482126 | 45.19 | 0.0001 |
| Error | 4074 | 5813.115304 | 1.426882 | | |
| Corrected Total | 4107 | 7941.025474 | | | |

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YR | 14 | 187.299147 | 13.378511 | 9.38 | 0.0001 |
| QT | 3 | 101.162621 | 33.720874 | 23.63 | 0.0001 |
| AREA | 4 | 973.402696 | 243.350674 | 170.55 | 0.0001 |
| QT*AREA | 12 | 375.713413 | 31.309451 | 21.94 | 0.0001 |

Table 5. Analysis of variance for Database-II in the west Atlantic from 1975-1996. R-square=0.25. CV=-33.3.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 64 | 3939.182643 | 61.549729 | 42.40 | 0.0001 |
| Error | 8079 | 11728.512298 | 1.451728 | | |
| Corrected Total | 8143 | 15667.694941 | | | |

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YR | 21 | 595.646562 | 28.364122 | 19.54 | 0.0001 |
| QT | 3 | 111.079688 | 37.026563 | 25.51 | 0.0001 |
| AREA | 4 | 140.664084 | 35.166021 | 24.22 | 0.0001 |
| GEAR | 3 | 68.207012 | 22.735671 | 15.66 | 0.0001 |
| QT*AREA | 12 | 269.650486 | 22.470874 | 15.48 | 0.0001 |
| AREA*GEAR | 12 | 257.268348 | 21.439029 | 14.77 | 0.0001 |
| QT*GEAR | 9 | 141.345328 | 15.705036 | 10.82 | 0.0001 |

Table 6. Calculation of AIC for the models of CPUE standardization in the selected areas of high sailfish catch ratio. three columns indicate combinations of two way interaction introduced into the model.

The east Atlantic (Database-II, 1975-1996)

| 1st | 2nd | 3rd | No. of ob. | MSE | ln(MSE) | No. par. | AIC | Rank |
|---|---|---|---|---|---|---|---|---|
| no two way interactions | | | 2120 | 1.752 | 0.561 | 32 | 1253.04 | 6 |
| qt*area | | | 2120 | 1.731 | 0.549 | 40 | 1243.55 | 3 |
| qt*gear | | | 2120 | 1.709 | 0.536 | 40 | 1216.28 | 2 |
| area*gear | | | 2120 | 1.751 | 0.560 | 48 | 1283.25 | 8 |
| qt*area | qt*gear | | 2120 | 1.695 | 0.528 | 48 | 1215.21 | 1 |
| qt*area | area*gear | | 2120 | 1.730 | 0.548 | 56 | 1274.35 | 7 |
| qt*gear | area*gear | | 2120 | 1.708 | 0.535 | 56 | 1247.13 | 4 |
| qt*area | qt*gear | area*gear | 2120 | 1.695 | 0.528 | 64 | 1247.27 | 5 |

The east Atlantic (Database-I, 1956-1975)

| 1st | 2nd | 3rd | No. of ob. | MSE | ln(MSE) | No. par. | AIC | Rank |
|---|---|---|---|---|---|---|---|---|
| no two way interactions | | | 639 | 0.962 | -0.039 | 25 | 25.20 | 1 |
| area*qt | | | 639 | 0.948 | -0.053 | 33 | 32.05 | 2 |

Abbreviations: No. of ob., Number of observations; MSE, mean square error; No. par., number of parameter; AIC, Akaike's Information Criterion.

Table 7. Analysis of variance in sailfish designated area for Database-I in the east Atlantic from 1961-1975. R-square=0.40. CV=-189.2.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 18 | 391.318032 | 21.739891 | 22.60 | 0.0001 |
| Error | 620 | 596.401633 | 0.961938 | | |
| Corrected Total | 638 | 987.719664 | | | |

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YR | 14 | 72.830494 | 5.202178 | 5.41 | 0.0001 |
| QT | 3 | 89.639352 | 29.879784 | 31.06 | 0.0001 |
| AREA | 1 | 118.515587 | 118.515587 | 123.21 | 0.0001 |

Table 8. Analysis of variance in sailfish designated area for Database-II in the east Atlantic from 1975-1996. R-square=0.13. CV=-38.5.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 40 | 1001.168417 | 25.029210 | 14.11 | 0.0001 |
| Error | 3933 | 6974.239143 | 1.773262 | | |
| Corrected Total | 3973 | 7975.407560 | | | |

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YR | 21 | 414.755180 | 19.750247 | 11.14 | 0.0001 |
| QT | 3 | 113.303276 | 37.767759 | 21.30 | 0.0001 |
| AREA | 1 | 5.939784 | 5.939784 | 3.35 | 0.0673 |
| GEAR | 3 | 87.826555 | 29.275518 | 16.51 | 0.0001 |
| QT*GEAR | 9 | 81.970835 | 9.107871 | 5.14 | 0.0001 |
| QT*AREA | 3 | 106.785810 | 35.595270 | 20.07 | 0.0001 |

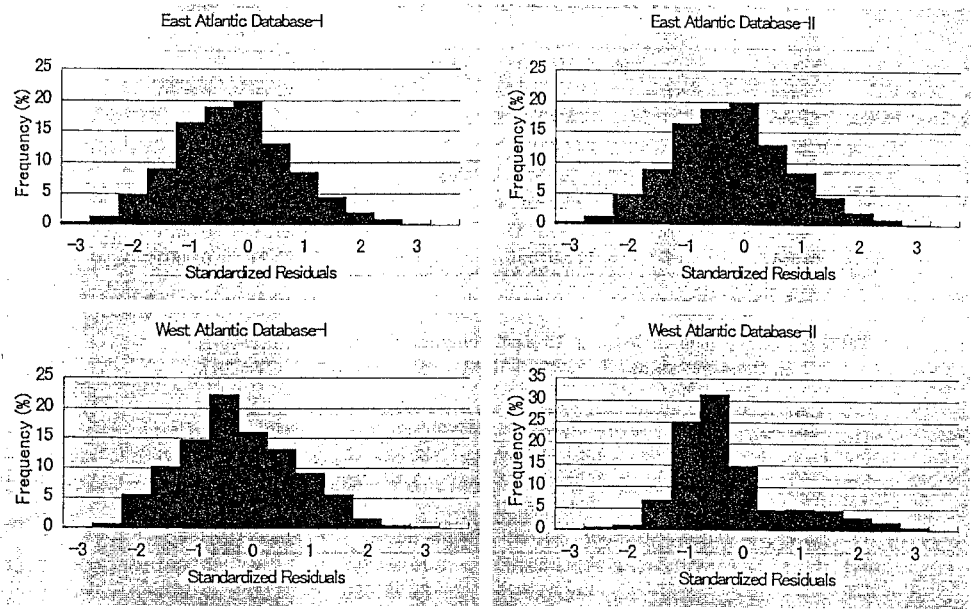


Fig. 1. Overall histgrams of standardized residuals from the final model.

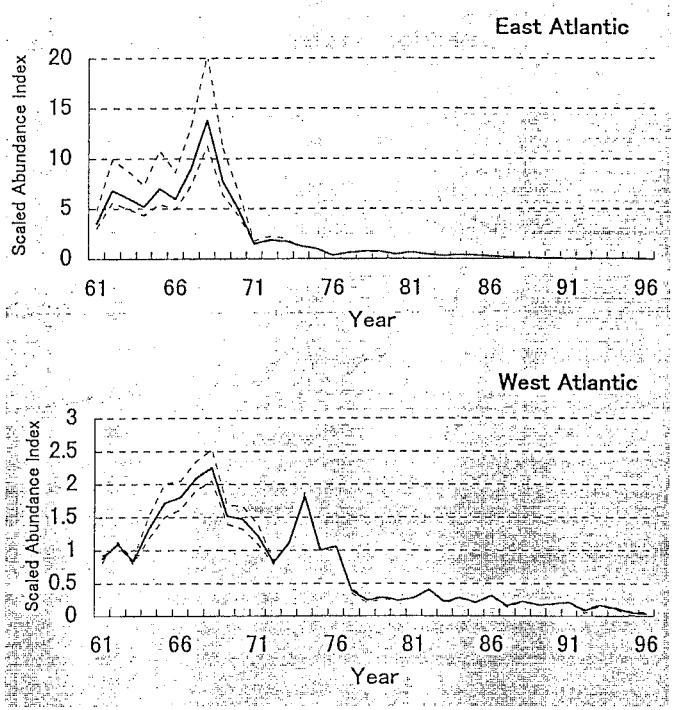


Fig. 2. Scaled annual abundance index for combined sailfish and spearfish caught by the Japanese longliners. Dotted lines show 95% confidence limits.

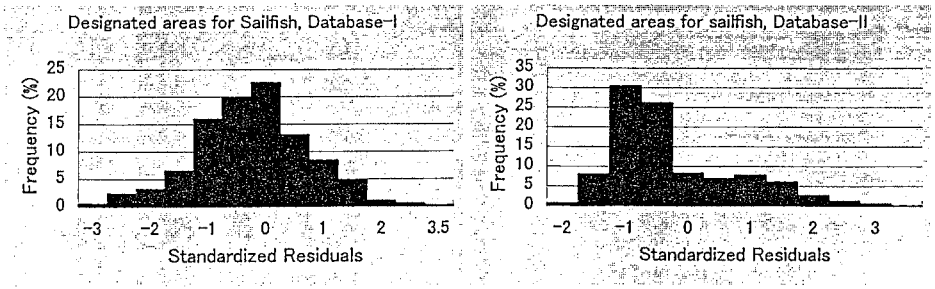


Fig. 3. Overall histograms of standardized residuals from the final model of the designated areas for sailfish.

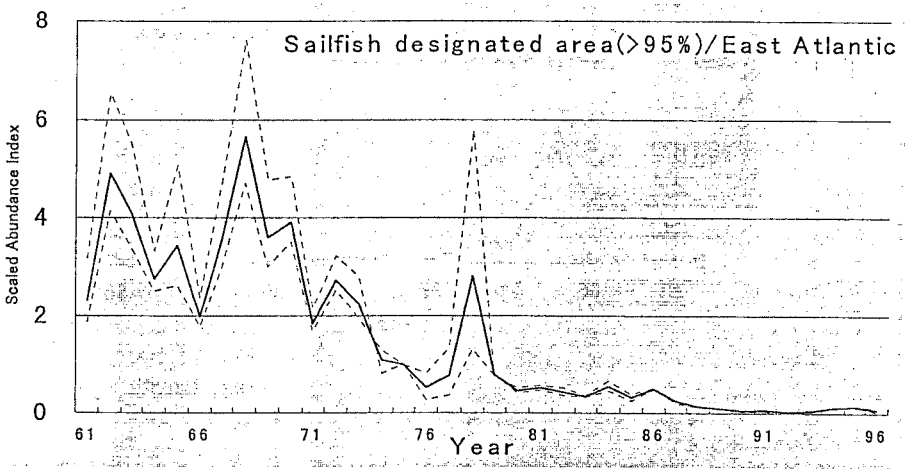


Fig. 4. Estimated sailfish annual abundance index caught by Japanese longliners. All the data were scaled to the value of 1975 set by 1.0. Dotted lines show 95% confidence limits.