# THE CPUE TREND FOR ATLANTIC WHITE MARLIN CAUGHT BY JAPANESE LONGLINE FISHERY

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*SUMMARY*

*CPUEs of White marlin (Tetrapturus albidus) from Japanese longline fishery were standardized by General Linear Model (GLM) and Honma method including the information of gear configuration in the model. Both CPUEs of GLM and Honma method showed a downward trend until late 1970' and became stable since then.*

*RESUME*

*La CPUE du makaire blanc (Tetrapturus albidus) dans la pêcherie palangrière japonaise a été standardisée au moyen du modèle linéaire généralisé (GLM) et de la méthode de Honma en incorporant au modèle l'information sur la configuration des engins. La CPUE du GLM et celle de la méthode de Honma montraient toutes deux une tendance décroissante jusqu'à la fin des années soixante-dix, et une stabilité depuis lors.*

*RESUMEN*

*Las CPUEs de aguja blanca (Tetrapturus albidus) de la pesquería de palangre japonesa se normalizaron por medio del Modelo Lineal Generalizado (GLM) y el método Honma, incluyendo la información de configuración del arte en el modelo. Tanto la CPUE del GLM como la del método Honma, mostraban una tendencia descendente hasta finales de los años 70, manteniéndose estables a partir de entonces.*

## 1. INTRODUCTION

The Japanese longline fishery caught Atlantic white marlin as bycatch targeting on yellowfin in early stage and bigeye and bluefin tuna in recently (Uozumi and Nakano SCRS/92/65). With changing targets, fishing ground were also changed widely. This fishery covers from the tropical to temperate waters except some areas of the western side of the Atlantic. The longline CPUEs for this species have been provided by Honma method (Kikawa and Honma 1978 and Watanabe et al. 1989). In this paper, standardized CPUE series from the Japanese longline fishery operating in the Atlantic were provided using General Linear Model (GLM) and Honma method.

## 2. MATERIALS AND METHODS

### 2.1 Basic data.

The basic data for this study were obtained from the Japanese longline fishery statistics compiled at the National Research Institute of Far Seas Fisheries (NRIFSF) for 1956-1989.

We used two sets of data. The data set 1 was sampling data including additional information on gear configuration, i.e., the number of branch line per basket (between floats), which is obtained from log-book records, and not raised to the total operations. While, data set 2 was same as Task II catch and effort statistics submitted to the ICCAT. In these data set, the data are aggregated to month and 5-degree area.

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CPUE was calculated as catch in number of fish per 1000 hooks. Observations with less than 5,000 hooks and 0 catch were excluded from the analysis.

**2.2 Adjustment for the difference of gear efficiency.**

The difference of gear efficiency in catching Swordfish by the Japanese longline fishery was reported by Koido and Yonemori (1986). They noted that CPUEs of deep longline gear were significantly higher than the conventional longline gear in the Gulf of Guinea area. Suzuki et al. (1977) showed a significant different in gear efficiency between the deep and regular longline for marlins in the Pacific. Then gear efficiency parameter was included in the GLM model analysis using data set 1.

**2.3 Selection of the model.**

For the analysis of data set 1, year, fishing season, fishing area and gear configuration were included as main effects in the model. Years ranged from 1975 to 1989. Quarter-of-the-year were selected as fishing season. After several preliminary runs, areas were selected as Fig.1 where significant catches and effort were made. Outsides of these areas were not included for analysis because of small number of observation. The Area 3 and 4 were made wider because these areas have not enough observation. With regard to gear configuration, 4 to 15 hooks between floats were observed in the data base. These 12 levels were categorized to 3 levels (4-7, 8-11 and 12-15 hooks between the floats) according to the report of Uozumi et al. (1992) after preliminary runs using all 12 levels of gear separately without any interaction term.

It was observed in the preliminary runs that 0 catch observations mostly have larger negative residual. Therefore, 0 catch observations were dropped from the analysis.

The multiplicative model was selected. The model is:

$$LOG\ (CPUE_{ijkl}) = \mu + Y_i + Q_j + A_k + G_l + Interaction + e_{ijkl}$$

Where LOG: natural logarithm,
$CPUE_{ijkl}$: nominal CPUE (catch in number per 1000 hooks, in year i, quarter j, subarea k and effect of gear l)

$\mu$ : overall mean,

$Y_i$: effect of year i,
$Q_j$: effect of quarter j,
$A_k$: effect of area k,
$G_l$: effect of gear l,
Interaction: any combination of two way interaction except for year term.

The best model was selected by AIC (Akaike's Information Criterion, Akaike 1973, 1974 and 1985) among the tested models.
AIC is:

$$AIC = X \log(MSE) + 2Y$$

where X is the number of observations, MSE is mean square error and Y is number of parameters to be estimated.

Considering the stock structure and ICCAT area for Atlantic white marlin, CPUEs were estimated for four units i.e., Total Atlantic (Areas 1-11 in Fig.1), North Atlantic (Areas 1-7), South Atlantic (Areas 8-11) and North-west Atlantic (Areas 1-4).

For the analysis of data set 2, year, fishing season and fishing area were included as main effects in the model. Years covered area from 1960 to 1989. Fishing season were same as data set 1. Areas were selected as Fig.5 where significant catches and effort were made. Outsides of these areas were not included for analysis because of small number of observation. The 0 catch observations were dropped from the analysis.

The multiplicative model was selected. The model is not included gear effect. The best model was selected by AIC among the tested models. CPUE was only estimated for Total Atlantic.

Analysis was made through computer software, 'SAS Ver. 6.03' on the UNIX workstation HP425t. In General Linear Model procedure on 'SAS', standards at the main effect were placed on the level which was assigned the largest number, i.e., last year, quarter, etc.

### 2.4 Honma method

For comparison of the results, the Honma method (Honma 1974) was adopted for the analysis. CPUEs were calculated for each North, South and total Atlantic unit using time series data of 1956-1989. The "average years period" were calculated using 1970-1989. 0 catch records were included for analysis.

After 1978, the data with the US 200 mile area were excluded from calculation because Japanese fishermen were not allowed to keep billfish by the US regulation.

## 3.RESULTS AND DISCUSSION

For data set 1, number of observations fitted to the final model were shown in Table 1 by main effect. The model with all the two way interaction was determined to be the best for Total, North, North-west and South Atlantic. In each unit area, it was found that some interaction term was not significant ($F < 2.0$). The model with some interaction term including YEAR was not estimated least square mean of LN(CPUE) because of not enough observation.

In the Total and North unit, the same model with QUARTER*AREA and AREA*GEAR in addition to all main efforts was selected (Table 2). For North-west and South unit, the same model with QUARTER*AREA, QUARTER*GEAR and AREA*GEAR in addition to all main efforts was selected.

The overall histograms of normalized residual from the final model were shown in Fig. 2. The distribution is close to normal distribution in most cases. In Fig. 3, also shown are the histograms of normalized residual by year. Some histograms are appeared far from normality probably due to small observations especially years from 1975 to 1980 of the South unit. The results of ANOVA indicated all models in Table 2 were statistically significant. The rate of variability explained by the final model(i.e., $R^2$) was in the range of 0.27-0.43. The highest $R^2$ was obtained for North-west unit ($R^2 = 0.43$) and next was 0.42 for Total Atlantic unit.

Relative difference in efficiency among gears were estimated as 1.0, 0.94 and 0.72 for 4-7, 8-11 and 12-15 hooks levels, respectively.

Estimated parameters, their standard error and standardized CPUEs were shown in Table 3. In Fig. 4, the standardized CPUEs were shown with lower and upper 95% confidence limits. All CPUE series indicate almost same trend except South unit which gradually decreased until 1985 and increased slightly after that. While the CPUE for South unit fluctuated until 1982 then continued to increase gradually.

For data set 2, number of observations fitted to the final model were shown in Table 4 by main effect. Two models were only estimated from the data set. The model with QUARTER*AREA was selected (Table 5).

The overall histograms of normalized residual from the final model were shown in Fig. 6. The distribution is close to normal distribution in most cases. In Fig. 8, also shown are the histograms of

normalized residual by year. The results of ANOVA indicated all models in Table 5 were statistically significant. The rate of variability explained by the final model(i.e., $R^2$) was in the range of 0.39-0.43.

Estimated parameters, their standard error and standardized CPUEs were shown in Table 6. In Fig. 7, the standardized CPUEs were shown with lower and upper 95% confidence limits. The CPUE series indicate down trend until late 1970' and stay same level.

The results of Honma methods were shown in Table 7 and Fig.9
which indicate almost same trends of GLM model. It took also accounts of effect of deep longline gear after 1978 using the efficiency of the gear obtained from GLM analysis.

Although no difference was shown in CPUE trends estimated by GLM and Honma method, we suggest the results of GLM analysis be used as better estimates of statistical superiority in GLM model. In any case, we should take care for interpretation of the results because of the difference between distribution of fish and effort as Uozumi and Nakano noticed in SCRS/92/65.

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**Table. 1. Number of observations in the final models of white marlin by main effect including gear effect.**

| Unit | Total Atlantic | North | North-west | South |
|---|---|---|---|---|
| Main Effect | No. of Observation | No. of Observation | No. of Observation | No. of Observation |
| YEAR | | | | |
| 75 | 226 | 197 | 103 | 29 |
| 76 | 204 | 192 | 143 | 12 |
| 77 | 132 | 105 | 62 | 27 |
| 78 | 117 | 94 | 24 | 23 |
| 79 | 145 | 91 | 47 | 54 |
| 80 | 218 | 151 | 34 | 67 |
| 81 | 319 | 233 | 100 | 86 |
| 82 | 427 | 315 | 83 | 112 |
| 83 | 187 | 105 | 37 | 82 |
| 84 | 286 | 147 | 50 | 139 |
| 85 | 422 | 213 | 46 | 209 |
| 86 | 277 | 149 | 52 | 128 |
| 87 | 223 | 123 | 76 | 100 |
| 88 | 347 | 138 | 42 | 209 |
| 89 | 487 | 246 | 55 | 241 |
| QT | | | | |
| 1 | 1020 | 468 | 285 | 552 |
| 2 | 633 | 462 | 198 | 171 |
| 3 | 1205 | 901 | 332 | 304 |
| 4 | 1159 | 668 | 139 | 491 |
| GEAR | | | | |
| 1 | 1286 | 1052 | 954 | 234 |
| 2 | 1591 | 1076 | 649 | 515 |
| 3 | 1140 | 371 | 279 | 769 |
| AREA | | | | |
| 1 | 285 | 285 | 285 | |
| 2 | 198 | 198 | 198 | |
| 3 | 332 | 332 | 332 | |
| 4 | 139 | 139 | 139 | |
| 5 | 303 | 303 | | |
| 6 | 702 | 702 | | |
| 7 | 540 | 540 | | |
| 8 | 260 | | | 260 |
| 9 | 187 | | | 187 |
| 10 | 460 | | | 460 |
| 11 | 611 | | | 611 |
| Total | 4017 | 2499 | 954 | 1518 |

**Table. 2. Results of ANOVA for GLM analysis applied to Atlantic white marlin caught by the Japanese longline fishery.**

**Total Atlantic**

| Model | Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F Value | R-Square | AIC |
|---|---|---|---|---|---|---|---|
| Y+Q+A+G | Model | 29 | 3023.79 | 104.27 | 72.52 | 0.346 | 1484.948 |
| | Error | 3987 | 5727.42 | 1.44 | | | |
| | Total | 4016 | 8751.21 | | | | |
| Y+Q+A+G +Q*A | Model | 59 | 3600.03 | 61.02 | 46.87 | 0.411 | 1118.988 |
| | Error | 3957 | 5151.18 | 1.3 | | | |
| | Total | 4016 | 8751.21 | | | | |
| Y+Q+A+G +A*G | Model | 49 | 3088.03 | 63.02 | 44.15 | 0.353 | 1479.635 |
| | Error | 3967 | 5663.17 | 1.43 | | | |
| | Total | 4016 | 8751.21 | | | | |
| Y+Q+A+G +Q*A+A*G | Model | 79 | 3658.29 | 46.31 | 35.8 | 0.418 | 1113.298 |
| | Error | 3937 | 5092.92 | 1.29 | | | |
| | Total | 4016 | 8751.21 | | | | |

**Table 2. Continued..**

**North Unit**

| Model | Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F Value | R-Square | AIC |
|---|---|---|---|---|---|---|---|
| Y+Q+A+G | Model | 25 | 1528.01 | 61.12 | 37.93 | 0.277 | 1218.423 |
| | Error | 2473 | 3985.43 | 1.61 | | | |
| | Total | 2498 | 5513.45 | | | | |
| Y+Q+A+G +Q*A | Model | 43 | 2037.81 | 47.39 | 33.47 | 0.37 | 912.388 |
| | Error | 2455 | 3475.64 | 1.42 | | | |
| | Total | 2498 | 5513.45 | | | | |
| Y+Q+A+G +A*G | Model | 37 | 1565.04 | 42.3 | 26.36 | 0.284 | 1219.096 |
| | Error | 2461 | 3948.41 | 1.6 | | | |
| | Total | 2498 | 5513.45 | | | | |
| Y+Q+A+G +Q*A+A*G | Model | 55 | 2073.61 | 37.7 | 26.78 | 0.379 | 910.516 |
| | Error | 2443 | 3439.84 | 1.41 | | | |
| | Total | 2498 | 5513.45 | | | | |

**Northwest Unit**

| Model | Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F Value | R-Square | AIC |
|---|---|---|---|---|---|---|---|
| Y+Q+A+G | Model | 22 | 1210.99 | 55.05 | 25.04 | 0.372 | 774.114 |
| | Error | 931 | 2026.5 | 2.2 | | | |
| | Total | 953 | 3257.49 | | | | |
| Y+Q+A+G +Q*A | Model | 31 | 1311.26 | 42.3 | 20.04 | 0.403 | 742.19 |
| | Error | 922 | 1946.23 | 2.11 | | | |
| | Total | 953 | 3257.49 | | | | |
| Y+Q+A+G +Q*G | Model | 28 | 1312.12 | 46.86 | 22.28 | 0.403 | 737.767 |
| | Error | 925 | 1945.37 | 2.1 | | | |
| | Total | 953 | 3257.49 | | | | |
| Y+Q+A+G +Q*A+Q | Model | 37 | 1370.53 | 37.04 | 17.98 | 0.421 | 726.687 |
| | *G Error | 916 | 1886.97 | 2.06 | | | |
| | Total | 953 | 3257.49 | | | | |
| Y+Q+A+G +Q*A+Q +A*G | Model | 43 | 1395.95 | 32.43 | 15.87 | 0.429 | 725.746 |
| | *G Error | 910 | 1861.54 | 2.05 | | | |
| | Total | 953 | 3257.49 | | | | |

**South Unit**

| Model | Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F Value | R-Square | AIC |
|---|---|---|---|---|---|---|---|
| Y+Q+A+G | Model | 22 | 482.18 | 21.92 | 20.07 | 0.228 | 156.541 |
| | Error | 1495 | 1632.67 | 1.09 | | | |
| | Total | 1517 | 2114.84 | | | | |
| Y+Q+A+G +Q*A | Model | 31 | 509.2 | 16.43 | 15.2 | 0.241 | 149.211 |
| | Error | 1486 | 1605.65 | 1.08 | | | |
| | Total | 1517 | 2114.84 | | | | |
| Y+Q+A+G +A*G | Model | 28 | 499.66 | 17.84 | 16.45 | 0.236 | 152.201 |
| | Error | 1489 | 1615.18 | 1.08 | | | |
| | Total | 1517 | 2114.84 | | | | |
| Y+Q+A+G +Q*A+A | Model | 37 | 526.66 | 14.23 | 13.26 | 0.249 | 144.614 |
| | *G Error | 1480 | 1588.19 | 1.07 | | | |
| | Total | 1517 | 2114.84 | | | | |
| Y+Q+A+G +Q*A+Q +A*G | Model | 43 | 542.19 | 12.61 | 11.82 | 0.256 | 141.691 |
| | *G Error | 1474 | 1572.65 | 1.07 | | | |
| | Total | 1517 | 2114.84 | | | | |

**Table. 3. Standardized CPUE for Atlantic white marlin, 1975-1989.**

| | TOTAL ATLANTIC | | | NORTH ATLANTIC | | | NORTHWEST ATLANTIC | | | SOUTH ATLANTIC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Parameter | Standard Error | Standar-dized CPU | Parameter | Standard Error | Standar-dized CPU | Parameter | Standard Error | Standar-dized CPU | Parameter | Standard Error | Standar-dized CPU |
| 75 | -1.9106 | 0.1072 | 0.1480 | -1.6405 | 0.1310 | 0.1939 | -0.5121 | 0.2735 | 0.5992 | -2.4660 | 0.2279 | 0.0849 |
| 76 | -1.6526 | 0.1102 | 0.1916 | -1.3745 | 0.1298 | 0.2530 | -0.7212 | 0.2568 | 0.4862 | -2.6307 | 0.3321 | 0.0720 |
| 77 | -1.9892 | 0.1247 | 0.1368 | -1.9111 | 0.1521 | 0.1479 | -1.3398 | 0.2934 | 0.2619 | -1.7294 | 0.2429 | 0.1774 |
| 78 | -1.6116 | 0.1268 | 0.1996 | -1.3665 | 0.1526 | 0.2550 | -1.3453 | 0.3713 | 0.2605 | -1.9553 | 0.2684 | 0.1415 |
| 79 | -2.0283 | 0.1151 | 0.1316 | -1.8512 | 0.1513 | 0.1570 | -1.5899 | 0.3063 | 0.2039 | -2.2501 | 0.1851 | 0.1054 |
| 80 | -1.9458 | 0.0988 | 0.1429 | -1.4976 | 0.1296 | 0.2237 | -1.1108 | 0.3376 | 0.3293 | -2.8458 | 0.1520 | 0.0581 |
| 81 | -2.0589 | 0.0862 | 0.1276 | -1.9281 | 0.1126 | 0.1454 | -1.6772 | 0.2538 | 0.1869 | -2.1738 | 0.1386 | 0.1137 |
| 82 | -2.2537 | 0.0800 | 0.1050 | -1.9759 | 0.1046 | 0.1386 | -1.8219 | 0.2588 | 0.1617 | -2.7676 | 0.1285 | 0.0628 |
| 83 | -2.3134 | 0.1033 | 0.0989 | -2.0562 | 0.1443 | 0.1279 | -2.1140 | 0.3241 | 0.1208 | -2.7070 | 0.1405 | 0.0667 |
| 84 | -2.1857 | 0.0900 | 0.1124 | -1.8347 | 0.1306 | 0.1597 | -1.9583 | 0.2949 | 0.1411 | -2.7000 | 0.1156 | 0.0672 |
| 85 | -2.2629 | 0.0789 | 0.1040 | -2.0873 | 0.1148 | 0.1240 | -1.9450 | 0.2968 | 0.1430 | -2.5813 | 0.1024 | 0.0757 |
| 86 | -2.0595 | 0.0902 | 0.1275 | -1.9161 | 0.1273 | 0.1472 | -1.9199 | 0.2952 | 0.1466 | -2.3120 | 0.1212 | 0.0991 |
| 87 | -1.9204 | 0.0962 | 0.1465 | -1.7381 | 0.1349 | 0.1759 | -1.4227 | 0.2645 | 0.2411 | -2.2261 | 0.1321 | 0.1079 |
| 88 | -1.9515 | 0.0864 | 0.1421 | -1.7487 | 0.1300 | 0.1740 | -1.4815 | 0.3046 | 0.2273 | -2.2535 | 0.1105 | 0.1050 |
| 89 | -1.9157 | 0.0789 | 0.1472 | -1.7992 | 0.1119 | 0.1654 | -1.3047 | 0.2785 | 0.2713 | -2.1297 | 0.1070 | 0.1189 |

**Table. 4. Number of observations in the final models by main effect without gear effect.**

| Main Effect | No. of Observation | Main Effect | No. of Observation |
|---|---|---|---|
| Year 60 | 93 | 82 | 233 |
| 61 | 174 | 83 | 133 |
| 62 | 245 | 84 | 187 |
| 63 | 337 | 85 | 249 |
| 64 | 434 | 86 | 177 |
| 65 | 527 | 87 | 127 |
| 66 | 345 | 88 | 218 |
| 67 | 283 | 89 | 293 |
| 68 | 237 | QT 1 | 1308 |
| 69 | 213 | 2 | 1557 |
| 70 | 269 | 3 | 2057 |
| 71 | 355 | 4 | 1616 |
| 72 | 200 | Area 1 | 634 |
| 73 | 141 | 2 | 828 |
| 74 | 125 | 3 | 809 |
| 75 | 179 | 4 | 484 |
| 76 | 152 | 5 | 925 |
| 77 | 98 | 6 | 785 |
| 78 | 80 | 7 | 800 |
| 79 | 111 | 8 | 1273 |
| 80 | 135 | | |
| 81 | 188 | Total | 6538 |

**Table 5. Results of ANOVA for GLM analysis without gear effect applied to Atlantic white marlin caught by the Japanese longline fishery.**

TOTAL ATLANTIC

| Model | Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F Value | R square | AIC |
|---|---|---|---|---|---|---|---|
| Y+Q+A | Model | 39 | 8841.24 | 226.7 | 107.85 | 0.393 | 4862.761 |
| | Error | 6498 | 13658.27 | 1.44 | | | |
| | Total | 6537 | 22499.51 | | | | |
| Y+Q+A +Q*A | Model | 60 | 9721.2 | 162.02 | 82.12 | 0.432 | 4450.501 |
| | Error | 6477 | 12778.31 | 1.3 | | | |
| | Total | 6537 | 22499.51 | | | | |

**Table. 6. Standardized CPUE of Atlantic white marlin for total Atlantic, 1960-1989 without gear effect.**

| Year | Stan Parameter | Standard Error | Standar-dized CPUE | Year | Sta Parameter | Standard Error | Standar-dized CPUE |
|---|---|---|---|---|---|---|---|
| 60 | -1.2000 | 0.1482 | 0.3012 | 75 | -1.8171 | 0.1069 | 0.1625 |
| 61 | -0.4355 | 0.1093 | 0.6469 | 76 | -1.5168 | 0.1162 | 0.2194 |
| 62 | -0.0243 | 0.0921 | 0.9760 | 77 | -2.1019 | 0.1432 | 0.1222 |
| 63 | -0.2766 | 0.0785 | 0.7584 | 78 | -2.0611 | 0.1585 | 0.1273 |
| 64 | -0.2618 | 0.0694 | 0.7696 | 79 | -2.3339 | 0.1351 | 0.0969 |
| 65 | -0.5980 | 0.0626 | 0.5499 | 80 | -2.3706 | 0.1221 | 0.0934 |
| 66 | -0.2712 | 0.0774 | 0.7625 | 81 | -2.4126 | 0.1034 | 0.0896 |
| 67 | -0.7418 | 0.0852 | 0.4763 | 82 | -2.4189 | 0.0933 | 0.0890 |
| 68 | -0.8463 | 0.0929 | 0.4290 | 83 | -2.4093 | 0.1230 | 0.0899 |
| 69 | -0.8891 | 0.0976 | 0.4110 | 84 | -2.5009 | 0.1038 | 0.0820 |
| 70 | -1.1625 | 0.0873 | 0.3127 | 85 | -2.4779 | 0.0907 | 0.0839 |
| 71 | -1.4042 | 0.0760 | 0.2456 | 86 | -2.3123 | 0.1070 | 0.0990 |
| 72 | -1.4991 | 0.1009 | 0.2233 | 87 | -2.1791 | 0.1259 | 0.1131 |
| 73 | -1.7415 | 0.1207 | 0.1753 | 88 | -2.4174 | 0.0970 | 0.0892 |
| 74 | -1.2915 | 0.1280 | 0.2749 | 89 | -2.2057 | 0.0837 | 0.1102 |

**Table. 7. Standardized CPUE of Atlantic white marlin for North, south and total Atlantic units, with gear effect (above) and without gear effect (below) using Honma method.**

| Year | NORTH C | NORTH X | NORTH U | SOUTH C | SOUTH X | SOUTH U | TOTAL C | TOTAL X | TOTAL U |
|---|---|---|---|---|---|---|---|---|---|
| WITH GEAR EFFECT | | | | | | | | | |
| 1978 | 1265 | 1479 | 0.086 | 328 | 351 | 0.094 | 1593 | 1862 | 0.086 |
| 1979 | 1750 | 2501 | 0.07 | 367 | 508 | 0.072 | 2117 | 2932 | 0.072 |
| 1980 | 4178 | 4749 | 0.088 | 192 | 604 | 0.032 | 4370 | 5479 | 0.08 |
| 1981 | 4555 | 10703 | 0.043 | 680 | 1871 | 0.036 | 5235 | 12745 | 0.041 |
| 1982 | 4069 | 7685 | 0.053 | 884 | 3718 | 0.024 | 4953 | 10958 | 0.045 |
| 1983 | 1239 | 2703 | 0.046 | 469 | 2108 | 0.022 | 1708 | 4426 | 0.039 |
| 1984 | 2182 | 3460 | 0.063 | 719 | 2062 | 0.035 | 2901 | 5444 | 0.053 |
| 1985 | 1933 | 4675 | 0.041 | 2589 | 4782 | 0.054 | 4522 | 9006 | 0.05 |
| 1986 | 2143 | 4629 | 0.046 | 2132 | 4942 | 0.043 | 4275 | 9071 | 0.047 |
| 1987 | 2070 | 5284 | 0.039 | 2202 | 2930 | 0.075 | 4272 | 8065 | 0.053 |
| 1988 | 2772 | 4255 | 0.065 | 2517 | 5012 | 0.05 | 5289 | 8742 | 0.061 |
| 1989 | 3062 | 7019 | 0.044 | 2933 | 5616 | 0.052 | 5995 | 12442 | 0.048 |
| WITHOUT GEAR EFFECT | | | | | | | | | |
| 1956 | 0 | 7 | 0 | 5 | 111 | 0.005 | 5 | 116 | 0.004 |
| 1957 | 145 | 85 | 0.172 | 683 | 553 | 0.124 | 828 | 577 | 0.144 |
| 1958 | 522 | 1545 | 0.034 | 833 | 921 | 0.09 | 1355 | 2417 | 0.056 |
| 1959 | 1133 | 2527 | 0.045 | 5646 | 3963 | 0.142 | 6779 | 5909 | 0.115 |
| 1960 | 1311 | 2588 | 0.051 | 9995 | 4560 | 0.219 | 11306 | 6291 | 0.18 |
| 1961 | 2155 | 1217 | 0.177 | 35959 | 7281 | 0.494 | 38114 | 7421 | 0.514 |
| 1962 | 20379 | 9243 | 0.22 | 93278 | 26496 | 0.352 | 113657 | 29853 | 0.381 |
| 1963 | 32521 | 27602 | 0.118 | 54417 | 15370 | 0.354 | 86938 | 39898 | 0.218 |
| 1964 | 75062 | 80707 | 0.093 | 87957 | 64347 | 0.137 | 163019 | 127718 | 0.128 |
| 1965 | 56828 | 38400 | 0.148 | 72497 | 58885 | 0.123 | 129325 | 83461 | 0.155 |
| 1966 | 50019 | 32897 | 0.152 | 39047 | 23253 | 0.168 | 89066 | 50975 | 0.175 |
| 1967 | 13011 | 9701 | 0.134 | 29499 | 25808 | 0.114 | 42510 | 28980 | 0.147 |
| 1968 | 12463 | 11089 | 0.112 | 30444 | 32457 | 0.094 | 42907 | 35475 | 0.121 |
| 1969 | 16248 | 11094 | 0.146 | 10728 | 15480 | 0.069 | 26976 | 23387 | 0.115 |
| 1970 | 19551 | 22265 | 0.088 | 12074 | 20762 | 0.058 | 31624 | 38185 | 0.083 |
| 1971 | 34152 | 35283 | 0.097 | 1921 | 1797 | 0.107 | 36073 | 35723 | 0.101 |
| 1972 | 12075 | 14825 | 0.081 | 2972 | 4989 | 0.06 | 15047 | 18129 | 0.083 |
| 1973 | 12469 | 11137 | 0.112 | 713 | 689 | 0.104 | 13182 | 11511 | 0.115 |
| 1974 | 12200 | 13503 | 0.09 | 179 | 158 | 0.114 | 12379 | 13494 | 0.092 |
| 1975 | 14678 | 26769 | 0.055 | 426 | 532 | 0.08 | 15104 | 25673 | 0.059 |
| 1976 | 15740 | 15585 | 0.101 | 54 | 124 | 0.043 | 15794 | 15012 | 0.105 |
| 1977 | 2628 | 5467 | 0.048 | 528 | 290 | 0.182 | 3156 | 5750 | 0.055 |
| 1978 | 1265 | 1478 | 0.086 | 328 | 351 | 0.094 | 1593 | 1859 | 0.086 |
| 1979 | 1750 | 2538 | 0.069 | 367 | 511 | 0.072 | 2117 | 2967 | 0.071 |
| 1980 | 4178 | 4807 | 0.087 | 192 | 648 | 0.03 | 4370 | 5571 | 0.078 |
| 1981 | 4555 | 10414 | 0.044 | 680 | 1967 | 0.035 | 5235 | 12514 | 0.042 |
| 1982 | 4069 | 8030 | 0.051 | 884 | 4656 | 0.019 | 4953 | 12029 | 0.041 |
| 1983 | 1239 | 2922 | 0.042 | 469 | 2635 | 0.018 | 1708 | 5067 | 0.034 |
| 1984 | 2182 | 3731 | 0.058 | 719 | 2653 | 0.027 | 2901 | 6198 | 0.047 |
| 1985 | 1933 | 4802 | 0.04 | 2589 | 6209 | 0.042 | 4522 | 10291 | 0.044 |
| 1986 | 2143 | 4442 | 0.048 | 2132 | 5978 | 0.036 | 4275 | 9716 | 0.044 |
| 1987 | 2070 | 4961 | 0.042 | 2202 | 3551 | 0.062 | 4272 | 8243 | 0.052 |
| 1988 | 2772 | 4125 | 0.067 | 2517 | 6498 | 0.039 | 5289 | 9783 | 0.054 |
| 1989 | 3062 | 7194 | 0.043 | 2933 | 8003 | 0.037 | 5995 | 14684 | 0.041 |

* C: catch, X: effective effort (x1000), U: CPUE(C/1000 hooks)

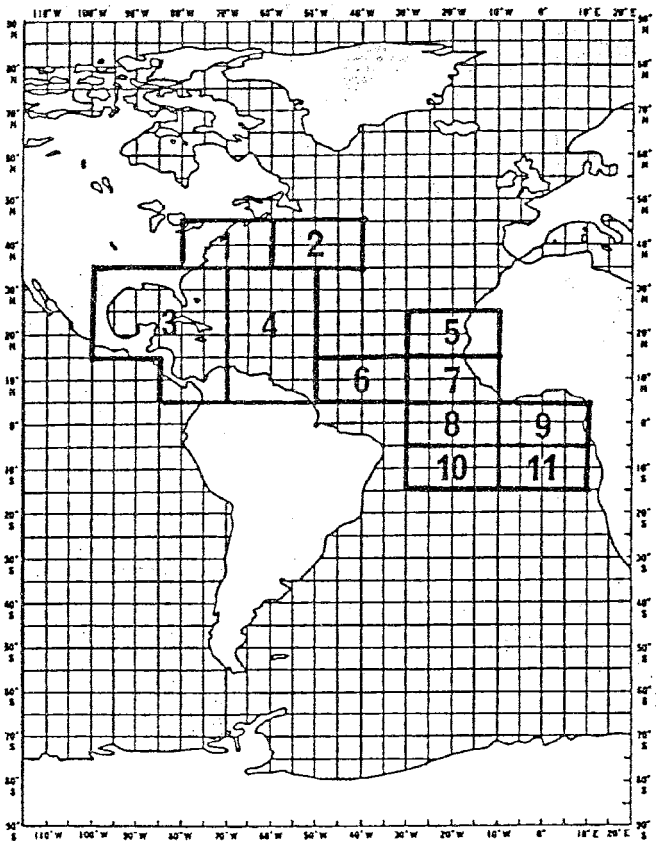


Figure 1. Area division used for GLM analysis for Atlantic white marlin caught by the Japanese longline fishery.

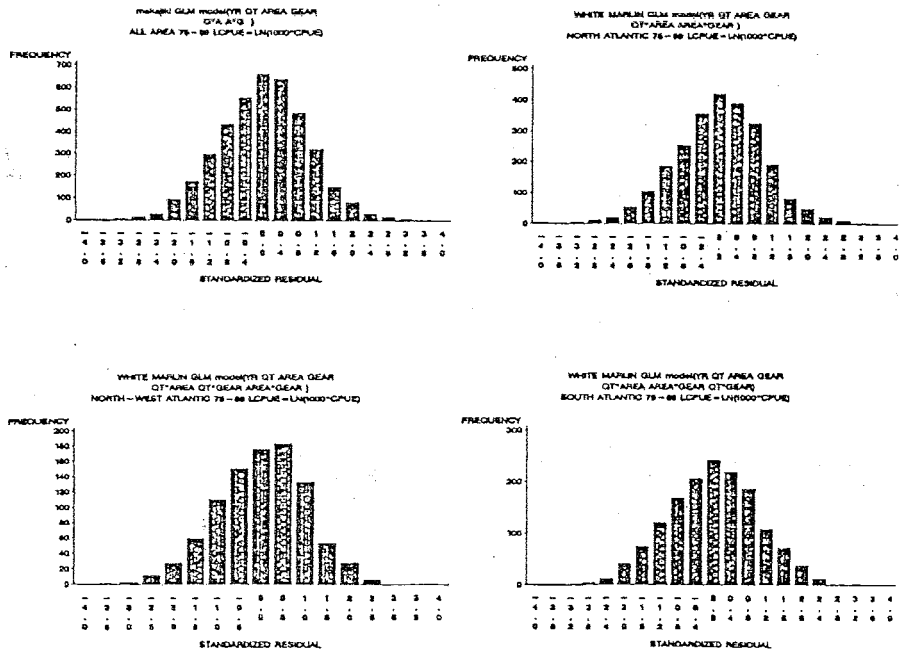


Figure 2. Overall histograms of normalized residual from the final model.

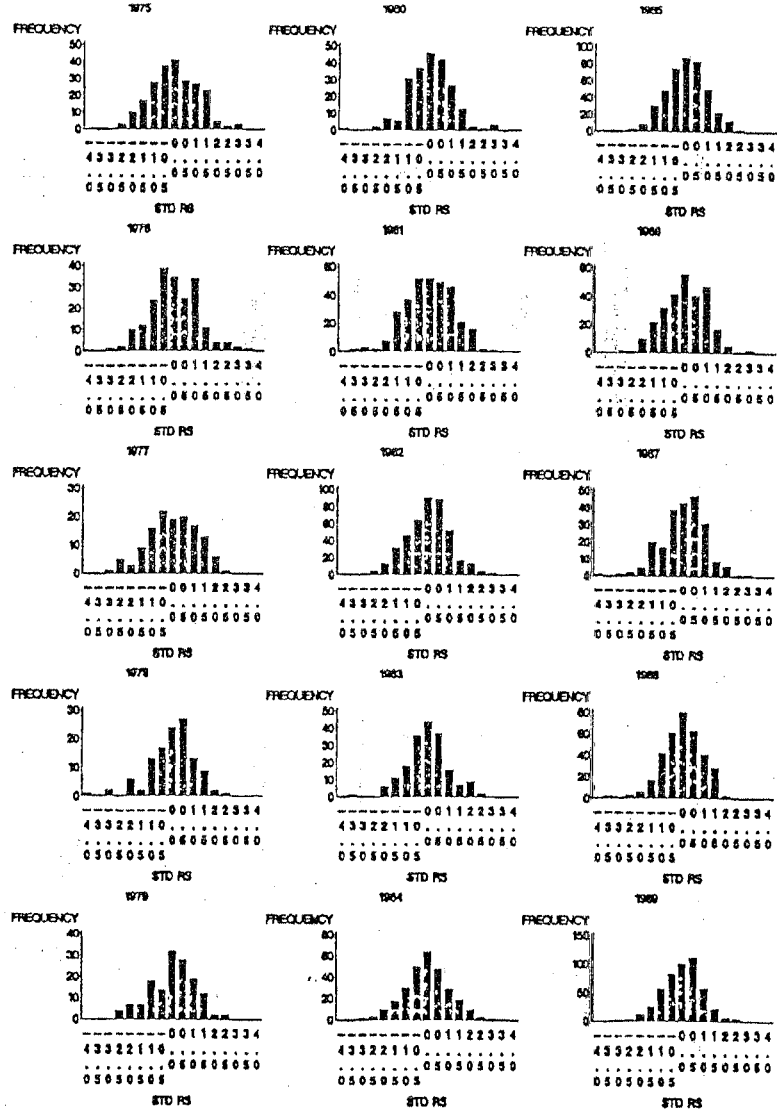

Figure 3. Histograms of normalized residual platted by year. All Atlantic unit.

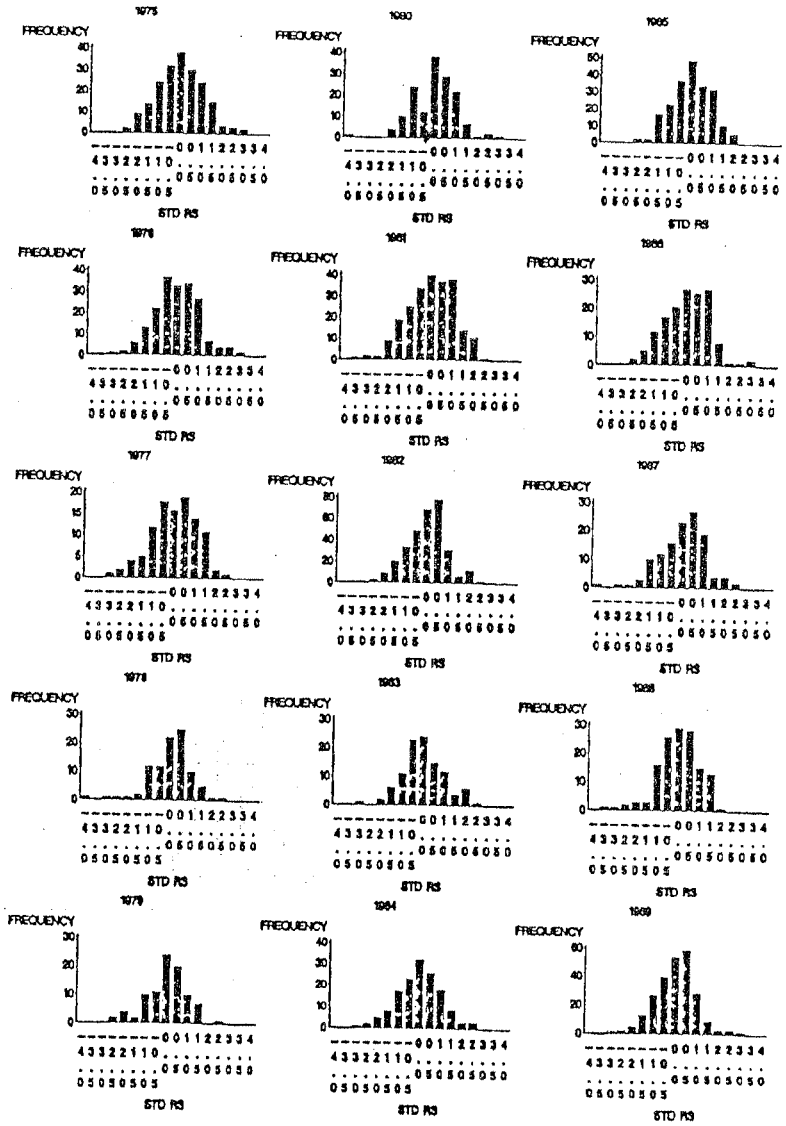

Fig. 3. Continued. North Unit.

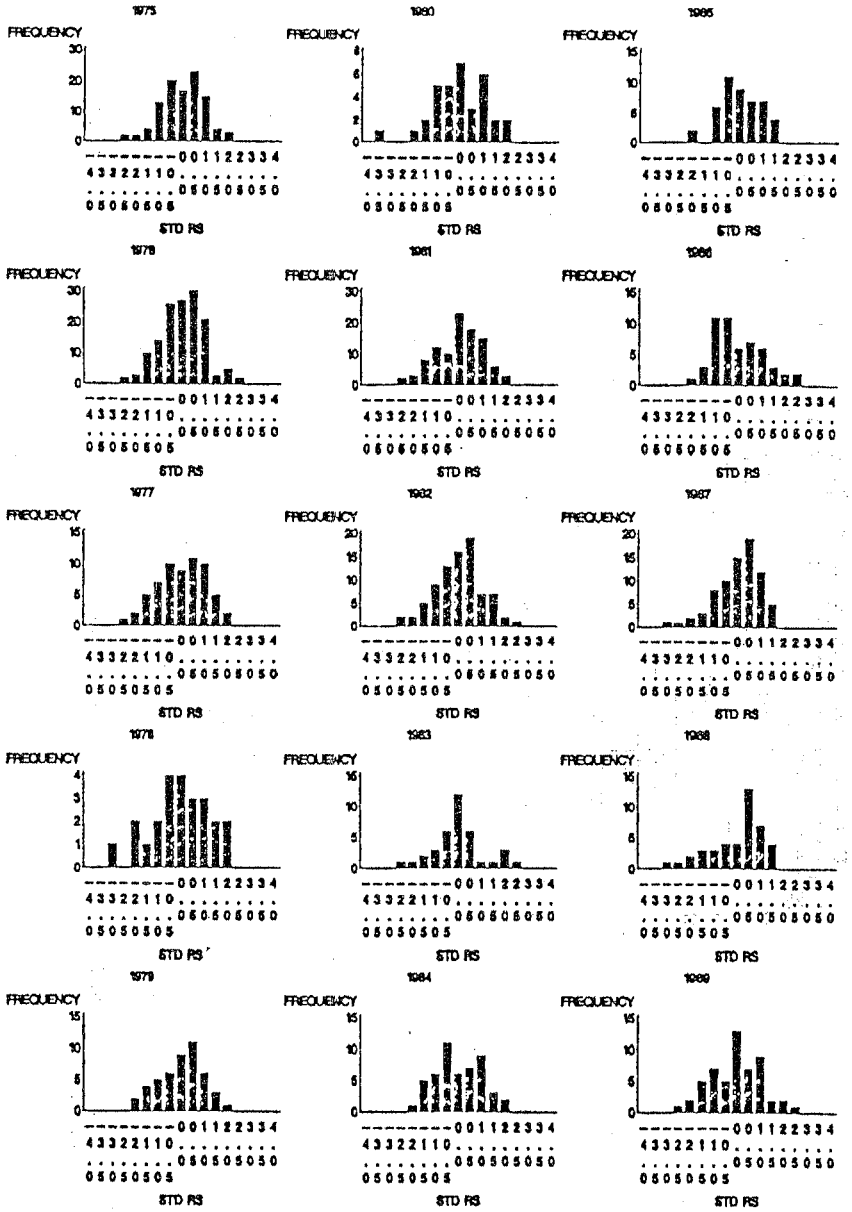


Figure 3. Continued. Northwest unti.

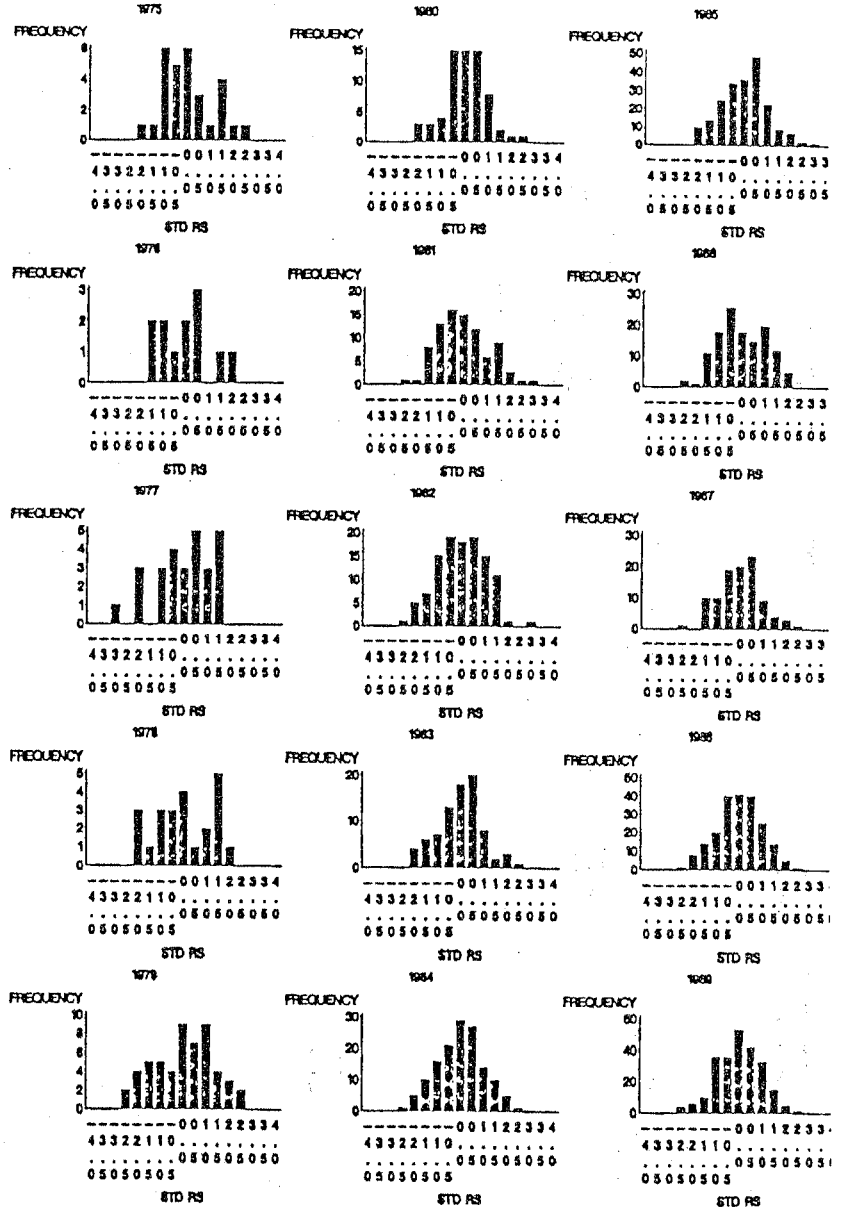


Fig. 3. Continued. South Unit.

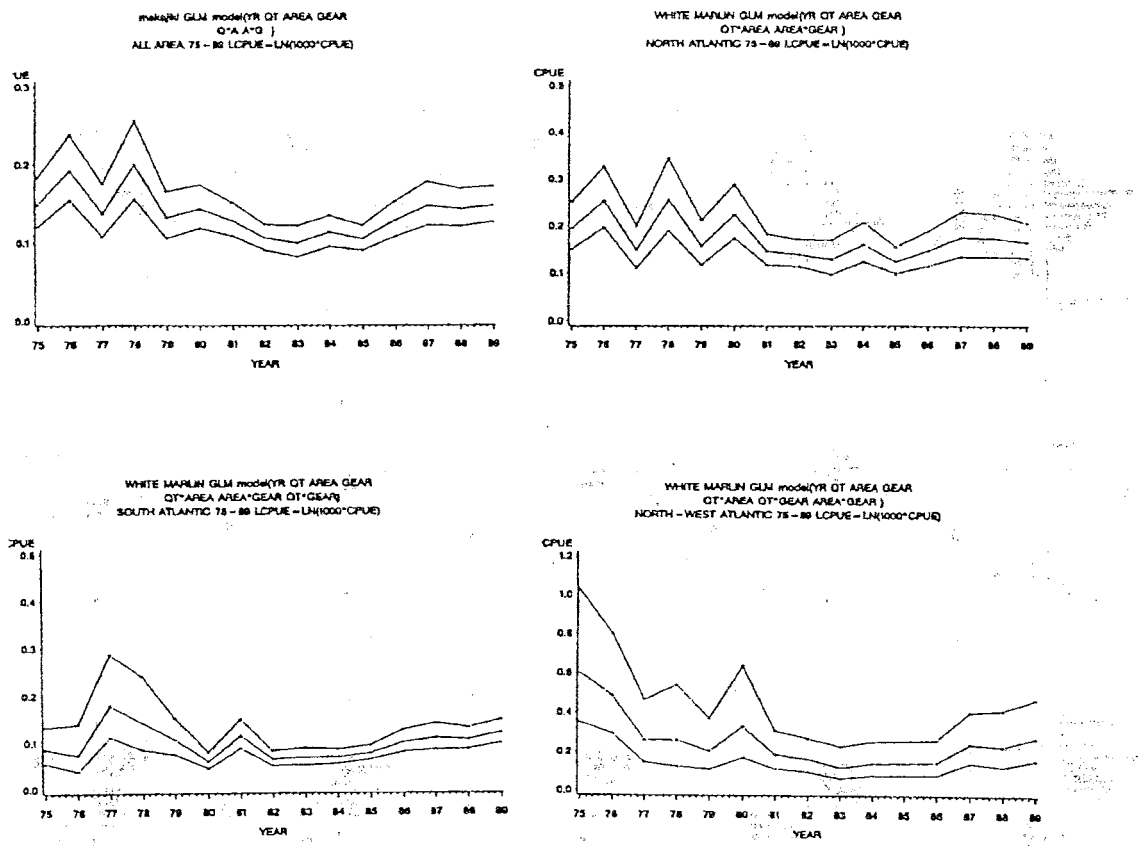


Figure 4. Annual change of standardized CPUE. Upper and lower line indicates 95% confidence limits.

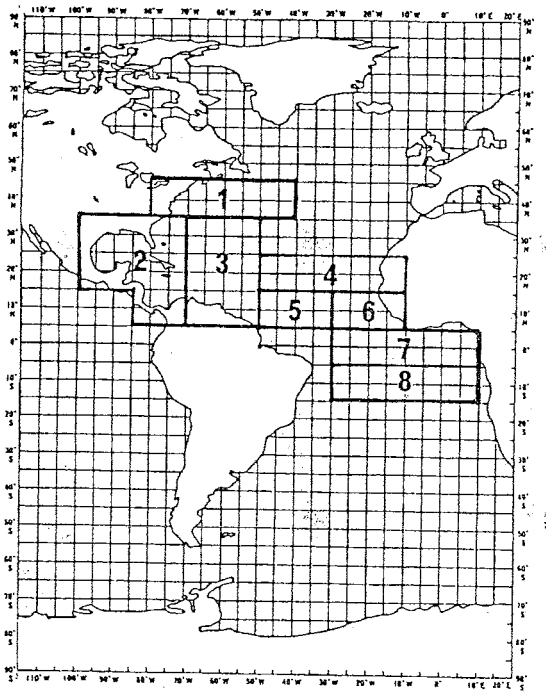


Figure 5. Division used for GLM analysis without gear effect for Atlantic white marlin caught by the Japanese longline fishery.

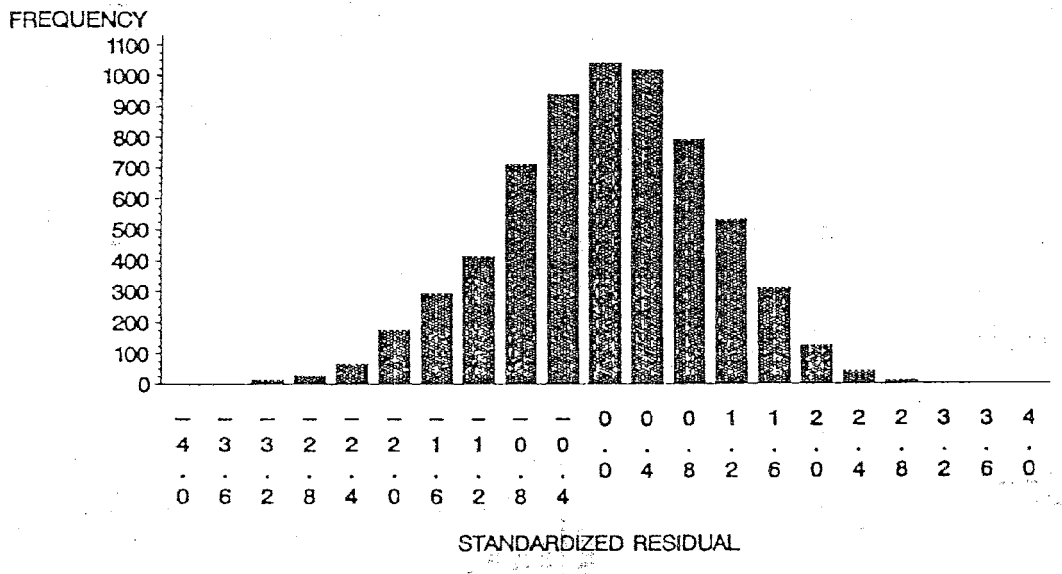


Figure 6. Overall histograms of normalized residual from the final model that excluded gear effect.

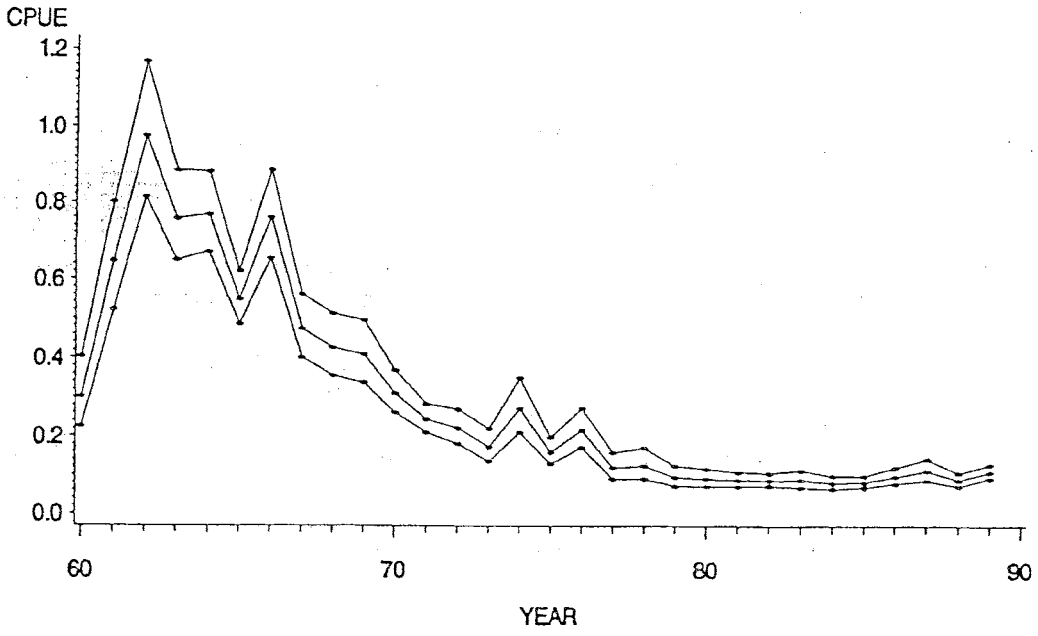


Figure 7. Annual change of standardized CPUE during 1960-1989. Upper and lower line indicates 95% confidence limits.

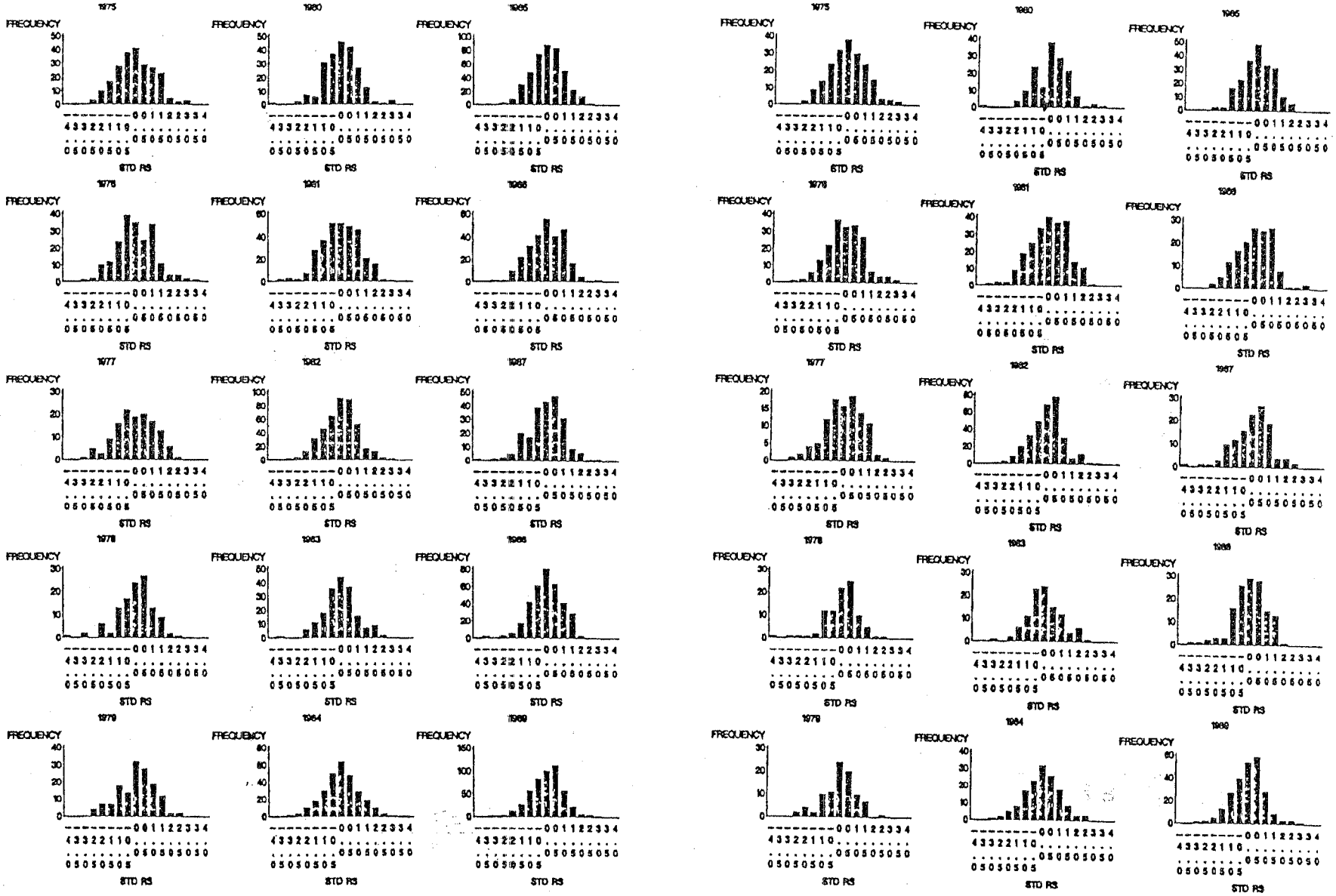


Figure 8. Histograms of normalized residual platted by year. The model excluded gear effect.

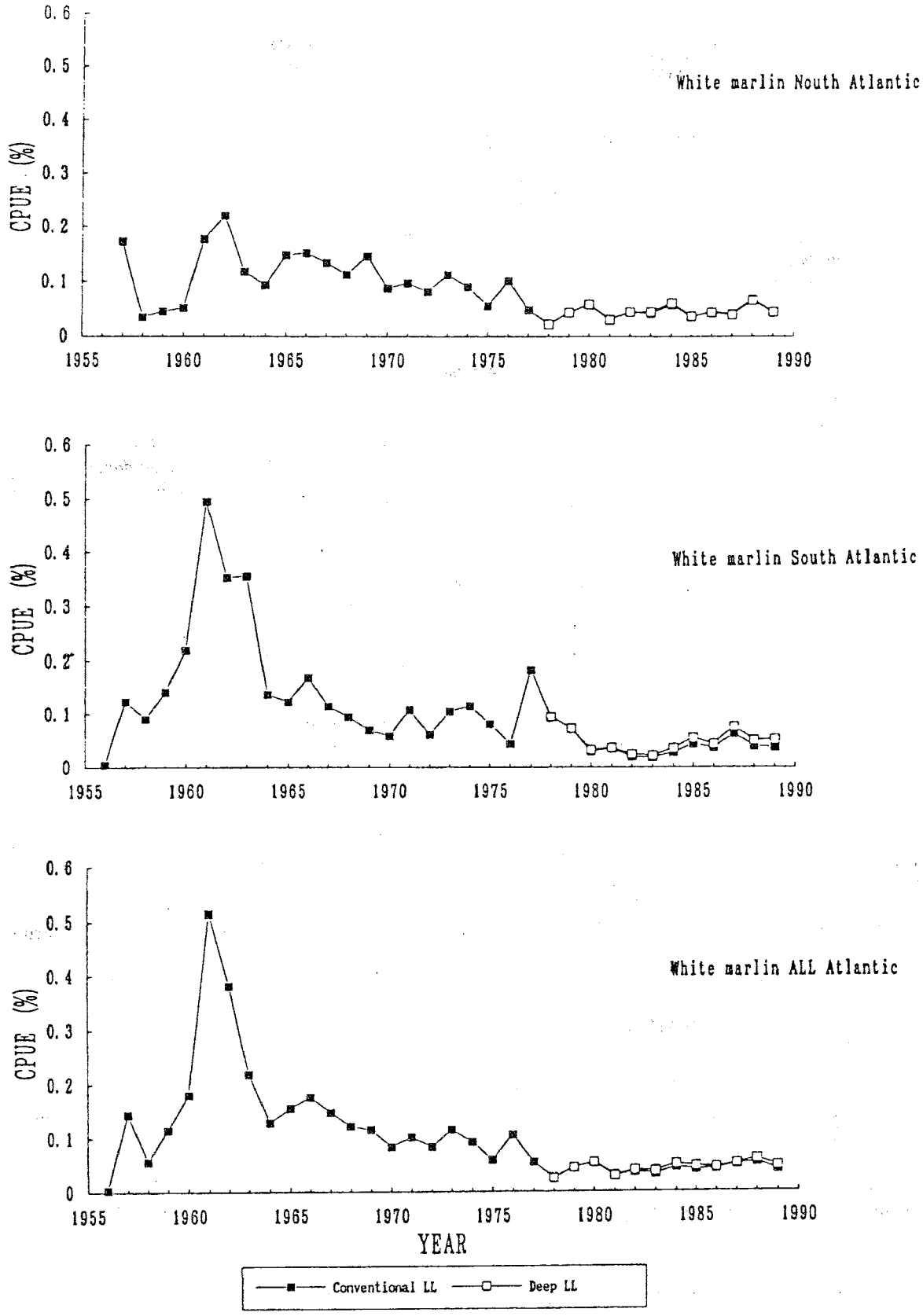


Figure 9. Annual change of standardized CPUE using the Honma method.