

STANDARDIZED CATCH RATES OF BLUEFIN TUNA FROM THE JAPANESE LONGLINE FISHERY  
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## SUMMARY

Data collected by observers aboard Japanese longline vessels fishing in the exclusive economic zone of the U.S. were used to develop standardized catch rates of bluefin tuna in the western North Atlantic Ocean, north of 35 degrees latitude.

Size was recorded for nearly every bluefin caught and was used to calculate catch rate at age for each set. A general linear model was used to develop age specific mean catch rates for 3 to 7 year old bluefin. Additional mean catch rates were developed for 3 to 5, and 6 to 7 year old bluefin age groups. Although the proportions of the total variation explained by the models were low, the catch rates of juvenile bluefin tuna population appear to be fairly stable.

## RESUME

Les données recueillies par des observateurs à bord de palangriers japonais pêchant dans la zone économique exclusive des Etats-Unis ont servi à élaborer un taux standard de capture pour le thon rouge dans l'Atlantique nord, au nord des 35<sup>o</sup> de latitude.

On a enregistré la taille de presque tous les thons rouges capturés, ce qui a servi à calculer le taux de capture par âge pour chaque opération. Un modèle linéaire généralisé a été utilisé pour élaborer le taux moyen spécifique de l'âge des thons rouges de 3 à 7 ans. D'autres taux moyens de capture ont été élaborés pour le thon rouge des groupes d'âge 3 à 5, et 6 à 7. Bien que le pourcentage de variation globale exposé par le modèle soit faible, le taux de capture de la population de thon rouge juvénile semble assez stable.

## RESUMEN

Los datos recopilados por observadores a bordo de barcos palangreros japoneses que faenan en la zona económica exclusiva de Estados Unidos, se utilizaron para desarrollar tasas de capturas estandarizadas de atún rojo en el Atlántico Norte occidental, al norte de los 35 grados de latitud.

Se registró la talla de prácticamente la totalidad de los ejemplares de atún rojo capturados, y se utilizó para calcular la tasa de captura por clase de edad para cada lance. Se empleó un modelo lineal generalizado para desarrollar las tasas medias de captura específicas de la edad para atunes rojos de 3 a 7 años. Se desarrollaron tasas medias de captura adicionales para los grupos de edad 3-5 y 6-7 de atún rojo. Aunque las proporciones de las variaciones totales explicadas mediante los modelos eran bajas, las tasas de captura de atún rojo juvenil parecen ser bastante estables.

## Introduction

U.S. observers have recorded catch and effort data from all Japanese longline vessels fishing within the U.S. Exclusive Economic Zone (EEZ) since 1982. The target species are the bluefin, bigeye and yellowfin tuna. The bluefin are generally targeted from November through February, otherwise, bigeye or yellowfin tuna are targeted.

Average catch rates may not reflect population trends because of variation among years in fishing strategy, gear, and environmental factors. Standardized abundance indices were developed by Turner (1987) and Davis and Turner (1988, 1989) using a general linear model (GLM). The purpose of this paper is to develop standardized catch rates of bluefin tuna following the same methods, of which trends of abundance may be revealed.

## Materials and Methods

U.S. observers record information on every animal caught by Japanese longline vessels fishing within the U.S. EEZ. Each record contains vessel identification, date, time, surface water temperature, location, and the gear configuration of each set made, as well as, the size and capture time of each animal. Length (centimeters) is recorded for nearly every tuna caught. Length may be recorded as straight or curved fork length, and as measured or estimated. Weight, if recorded, is measured as whole weight in kilograms.

Typical longline sets cover a great distance. Surface water temperature measured at the endpoints of a longline set may not reflect the environmental conditions along the longline. The presence of warm water bodies located at or near the location of a gear set was incorporated with the catch and effort data to help explain this potential source of variation. Weekly oceanographic analysis charts were examined to determine the presence of a warm

water body for each one degree square of latitude and longitude and then combined with the appropriate catch and effort record.

Observations used in the analyses were single sets. Sets that contained less than 1000 hooks or had missing lengths for more than 67% of the bluefin tuna on that set were not used in the analyses. Length was assigned to any unmeasured fish on a set by using the length composition of the measured tuna on that set.

Bluefin tuna were aged with the Parrack and Phares (1979) growth equation and the algorithm used by the SCRS in recent assessments. The equation included the variable  $T_0$  (Nichols 1985), using the value - 0.96 for 1985 through 1989. Catch rates at age were calculated for each set using catch at length. Bluefin over 9 years old were not included.

Examination of nominal catch rates by year and month (Table 1) revealed that December, January and February were the months of abundance for bluefin, therefore all other months were excluded from analyses.

The data were modified for logical years to occur from July through June, since the bluefin season for this fishery is divided by the calendar year. For example, November and December of 1984 were combined with January and February of 1985 for analyses.

Results of previous analyses revealed that 3 to 7 year old bluefin comprise most of the bluefin catch of this fishery (Turner 1987, Davis and Turner 1988 and 1989). Separate indices of abundance were developed for each age of 3 to 7 year old bluefin. Age specific mean catch rates by year were examined to determine age groups for separate analyses (Table 2). The 3 to 5 year old bluefin were the most frequently caught ages with similar trends in nominal catch rates. The 6 and 7 year old bluefin exhibited generally lower catch rates with trends that were similar for those ages and different from the 3 to 5 year old trends. Therefore,

separate analyses were also conducted on 3 to 5, and 6 to 7 year old bluefin tuna age groups.

The data used in the analyses were limited to insure a more balanced design; this was done by generally requiring that for each level of a main effect in the model there had to be at least 5 observations in at least 2 levels of every other main effect. This approach was relaxed for the 1989 effect in order to included in the analyses.

A general linear model (Draper and Smith 1966) was used to examine logged catch rates + 1 for differences among the effects of years, months, areas, number of hooks between floats, presence of a warm water body, and their interactions, with the exception of year, and surface water temperature. The frequency distributions of standardized residuals (observed minus predicted divided by standard error of the estimate) were examined at each level of the main effects to be sure that they approximated the normal distribution. F-tests were conducted on all main effects, interactions and the continuous variable water temperature. The F-tests were used to reduce the model until only significant main effects and interactions remained in the model. Insignificant main effects that were involved in significant interactions were retained in the final models. The standardized catch rates were calculated by keeping all parameters at zero except for year. The sum of the year estimate with the intercept was then antilogged to transform units from natural log back to catch per 1000 hooks.

### Results

After restricting the data to help insure a more balanced design, the following main effects and their associated levels were included in the initial analyses: YEAR; 1984, 1985, 1986, 1987, 1988, 1989; MONTH; January, February and December; AREA; 5 levels (Figure 1); NUMBER OF HOOKS BETWEEN FLOATS; 6,7,8; PRESENCE OF A

WARM WATER BODY; present, absent. There were sufficient data to test the interactions of all class variables. The numbers of observations by year, month and area are shown in Table 4.

Analyses were initiated with the 3 year old bluefin. The GLM procedure was applied with the initial model:

$$\begin{aligned} \ln(\text{CPUE} + 1) = & Y + M + A + P + N + M*A + M*P + M*N \\ & + A*P + A*N + P*N + T \end{aligned}$$

where CPUE = catch per 1000 hooks

Y = year

M = month

A = area

P = presence of a warm water body

N = number of hooks between floats

\* = interaction of 2 class variables

T = surface water temperature

GLM revealed that the interaction between the presence of a warm water body with number of hooks between floats was highly insignificant. Examination of the distributions of standardized residuals at the levels of the main effects appeared reasonable. The interaction term was removed from the model. Subsequent testing revealed that the interaction of month with presence of a warm water body, and the interaction of month with area were insignificant. Subsequent testing revealed all remaining interactions to be significant after removal of the preceding terms. The histogram of standardized residuals (Figure 2) for the model appeared reasonable and the model was accepted (Figure 3). The 1989 standardized catch rate is approximately the same as that of 1984. The 3 year olds exhibited an increase in 1985, otherwise the indices of abundance reveal a relatively stable trend (Table 3, Figure 4).

The initial model was next applied to the 4 year old bluefin. GLM revealed that the interaction between the presence of a warm water body with number of hooks between floats was insignificant. The distribution of standardized residuals at each level of the main effects appeared reasonable. The interaction term was removed and subsequently the interaction of month with the presence of a warm water body was removed. The distribution of standardized residuals for the model appeared reasonable (Figure 2) and the model was accepted (Figure 3). The standardized catch rates for 4 year olds appears relatively stable for 1984 through 1989 except for an apparent peak in 1987 (Figure 4).

The same initial procedures were applied to the 5, 6, and 7 year old bluefin respectively. The interaction of month with presence of a warm water body, and surface water temperature were sequentially removed from the 5 year old model. The interaction of the number of hooks between floats with area, and surface water temperature, were sequentially removed from the 6 year old model. Surface water temperature, the interaction of the presence of a warm water body with number of hooks between floats, and the interaction of area and the number of hooks between floats, were sequentially removed from the 7 year old model. The distributions of residuals at the levels of each of the main effects and for the 3 models appeared reasonable and were accepted (Figures 2, 3 and 5). The standardized mean catch rates for 5, 6, and 7 year olds did not show a consistent increase or decrease for 1984 through 1989. The three age groups exhibited a relatively low catch rate in 1986 followed by an increase in 1987. The 5 year olds have exhibited a gradual decline since 1987, whereas the 6 and 7 year olds have shown no trend (Figures 4 and 6).

Adequate models could not be developed for 8 or 9 year olds. Distributions of residuals were extremely peaked and skewed, and the coefficients of multiple determination ( $R^2$ ) were extremely low.

The final 3 sets of analyses were initiated on the 3 to 5, 6 to 7, and 8 to 9 year old bluefin age groups. Application of the GLM procedure on the 3 to 5 year olds resulted in the sequential removal of the interaction of the presence of a warm water body with number of hooks between floats, and the interaction of the presence of a warm water body with month. The distribution of standardized residuals for the model appeared quite reasonable and the model was accepted (Figures 3 and 7). The standardized mean catch rates for 1985 and 1987 were approximately equal. The model reflected the peak of the 3 year olds in 1985 and the peaks of the 4 and 5 year olds in 1987. The model suggests a gradual decline for the 3 to 5 year old age group since 1987 (Figure 8).

The application of the GLM procedure to the 6 to 7 year old age group resulted in the sequential removal of surface water temperature, the interaction of the presence of a warm water body with number of hooks between floats, and the interaction of area with the number of hooks between floats. The distributions of standardized residuals appeared reasonable and the model was accepted (Figures 3 and 7). The standardized mean catch rates appear relatively stable for 1984 through 1989 with a relative low point in 1986 (Figure 8).

An adequate model could not be developed for the 8 to 9 year old age group. Residuals distributions were highly peaked and skewed, and the  $R^2$  was very low.

#### Discussion

The standardized indices of abundance suggest that 7 year old bluefin are following a relatively flat trend. The 3 to 6 year olds are fluctuating, with the overall trend appearing stable. The relatively low index that occurred across all ages in 1986 is likely due to the low bluefin directed effort for that year, which followed the very high catches of 1985.

Relatively high amounts of variation that were not explained by the models (55 to 82%) were reflected in the confidence bands. As stated previously, the yearly indices were calculated by summing the year parameter estimate with the intercept estimate and transformed back to standard units. The intercept estimate was equal to the index for the standard year (1989), thus the confidence interval calculated for 1989 actually represents the variation for all levels of the model and is very likely to be much smaller than presented here. The combination of these data with those from the Canadian Japanese longline fishery in the Canadian EEZ may help explain some of this variation in future analyses.

#### Literature Cited

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Table 1. Nominal mean catch per 1000 hooks of bluefin tuna from the Japanese longline fishery in the U.S. EEZ by logical year by month. (Logical year defined to occur from July through June).

| Month | YEAR  |       |       |       |       |      |
|-------|-------|-------|-------|-------|-------|------|
|       | 84    | 85    | 86    | 87    | 88    | 89   |
| 1     | 13.95 | 16.96 | 5.48  | 21.7  | 14.86 | 0    |
| 2     | 8.49  | 29.57 | 10.77 | 0     | 14.73 | 0    |
| 3     | 0     | 20.18 | 0     | 0     | 0     | 0    |
| 4     | 0     | 0     | 0     | 0     | 0     | 0    |
| 5     | 0     | 0     | 0     | 0     | 0     | 0    |
| 6     | 0     | 0     | 0     | 0     | 0     | 0    |
| 7     | 0     | 0     | .01   | 0     | 0     | 0    |
| 8     | 0     | 0     | 0     | 0     | 0     | 0    |
| 9     | 0     | 0     | 0     | .01   | 0     | 0    |
| 10    | 0     | 0     | 0     | .01   | 0     | 0    |
| 11    | 0     | .01   | 0     | 0     | .05   | .04  |
| 12    | 1.55  | 13.06 | 0     | 10.99 | 6.23  | 9.15 |

Table 2. Age specific mean catch per 1000 hooks of bluefin tuna caught by the Japanese longline fishery in the U.S. EEZ by logical year occurring from July through June.

| Year | AGE  |      |      |      |      |
|------|------|------|------|------|------|
|      | 3    | 4    | 5    | 6    | 7    |
| 1984 | .56  | 1.84 | 2.36 | .56  | .05  |
| 1985 | 5.66 | 3.54 | 3.86 | 5.28 | 2.53 |
| 1986 | .38  | 3.90 | 1.37 | .64  | .40  |
| 1987 | 2.70 | 5.46 | 4.00 | 1.67 | .36  |
| 1988 | 1.98 | 2.64 | 2.18 | 1.65 | .69  |
| 1989 | 2.03 | 1.68 | 0.86 | 1.04 | .37  |

Table 3. Standardized mean catch per 1000 hooks from the General Linear Model analyses on bluefin tuna from the Japanese longline fishery in the U.S. EEZ for logical years occurring from July through June.

|      | AGE 3 | AGE 4 | AGE 5 | AGE 6 | AGE 7 | 3 TO 5 | 6 TO 7 |
|------|-------|-------|-------|-------|-------|--------|--------|
| 1984 | 1.782 | 2.448 | 1.037 | 0.294 | 0.284 | 2.333  | 0.223  |
| 1985 | 7.439 | 2.766 | 0.811 | 0.576 | 0.534 | 4.264  | 0.497  |
| 1986 | 2.582 | 1.770 | 0.445 | 0.170 | 0.331 | 1.526  | 0.145  |
| 1987 | 3.653 | 4.132 | 1.400 | 0.476 | 0.452 | 4.559  | 0.465  |
| 1988 | 2.670 | 2.211 | 0.978 | 0.489 | 0.449 | 2.432  | 0.418  |
| 1989 | 1.864 | 1.457 | 0.822 | 0.524 | 0.503 | 1.516  | 0.472  |

Table 4. Number of observations stratified by area, month and logical year used in developing standardized catch rates for bluefin tuna. (n = number observations, logical year defined to occur from July through June).

| YEAR | MONTH | AREA      |           |           |           |           |
|------|-------|-----------|-----------|-----------|-----------|-----------|
|      |       | 3966<br>n | 3967<br>n | 3968<br>n | 4066<br>n | 4067<br>n |
| 84   | 1     | 1         | 14        | 1         |           | 6         |
|      | 2     |           | 3         |           |           | 12        |
|      | 12    | 10        | 5         |           |           | 1         |
| 85   | 1     | 9         | 7         | 19        | 49        | 19        |
|      | 2     | 33        | 18        | 5         | 10        | 16        |
|      | 12    |           | 1         | 2         | 12        | 19        |
| 86   | 1     |           | 1         | 1         | 11        | 4         |
|      | 2     |           |           |           |           | 6         |
| 87   | 1     | 7         | 26        | 14        | 11        | 4         |
|      | 12    | 2         | 3         | 6         | 46        | 13        |
| 88   | 1     | 10        | 14        | 24        | 13        | 15        |
|      | 2     |           | 10        | 4         |           |           |
|      | 12    | 3         | 12        | 13        | 120       | 19        |
| 89   | 12    | 8         | 58        | 15        | 57        | 19        |

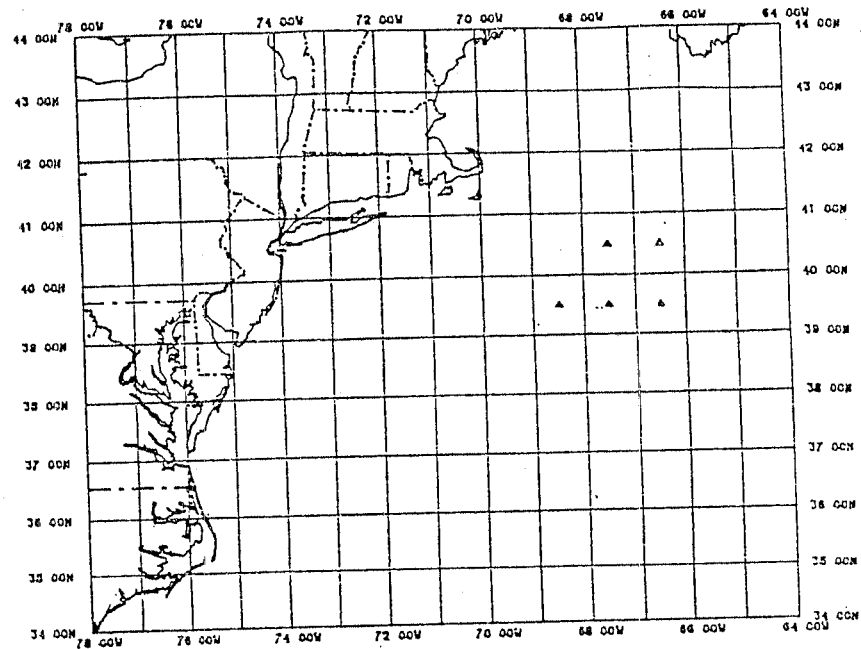


Figure 1. Map of the areas used in developing standardized catch rates for bluefin tuna from the Japanese longline fishery in the U.S. EEZ.

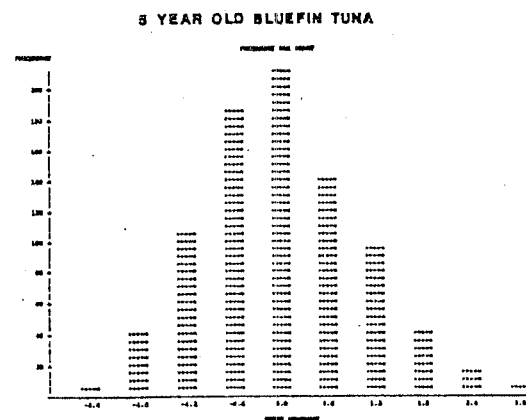
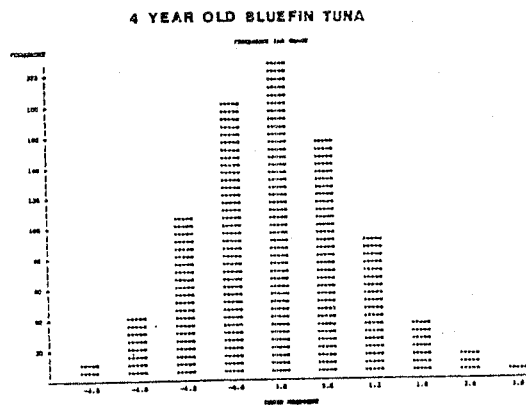
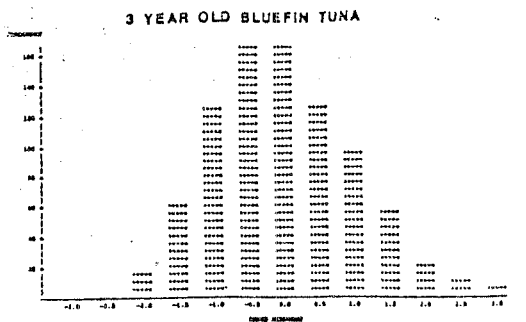


Figure 2. Standardized residual distribution for the final models of 3,4, and 5 year old bluefin tuna used in the development of standardized catch rates.

3 year old bluefin

$$\ln(\text{CPUE}+1) = Y + M + A + P + N + P*A + N*A + M*N + T$$

$$R^2 = 33 \quad \text{square root MSE} = .73$$

4 year old bluefin

$$\ln(\text{CPUE}+1) = Y + M + A + P + N + P*A + M*A + M*N + A * N + T$$

$$R^2 = 18 \quad \text{square root MSE} = .77$$

5 year old bluefin

$$\ln(\text{CPUE}+1) = Y + M + A + P + N + P*A + M*A + M + N + A*N + P*A$$

$$R^2 = 18 \quad \text{square root MSE} = .70$$

6 year old bluefin

$$\ln(\text{CPUE}+1) = Y + M + A + P + N + P*A + M*A + M*P + M*N$$

$$R^2 = 41 \quad \text{square root MSE} = .64$$

7 year old bluefin

$$\ln(\text{CPUE}+1) = Y + M + A + P + N + P*A + M*P + M*A + M*N$$

$$R^2 = 40 \quad \text{square root MSE} .50$$

3 to 5 year old bluefin

$$\ln(\text{CPUE}+1) = Y + M + A + P + N + P*A + M*A + A*N + M*N + T$$

$$R^2 = 27 \quad \text{square root MSE} .88$$

6 to 7 year old bluefin

$$\ln(\text{CPUE}+1) = Y + M + A + P + N + P*M + M*P + M*A + M*N$$

$$R^2 = 45 \quad \text{square root MSE} = .69$$

Figure 3. Final models used for developing standardized catch rates for bluefin tuna from the Japanese longline fishery in the U.S. EEZ. (CPUE = catch per 1000 hooks, Y = year, M = month, A = area, P = presence of a warm water body, N = number of hooks between floats, \* = interaction, T= temperature, MSE = mean square error, number of observations = 841).

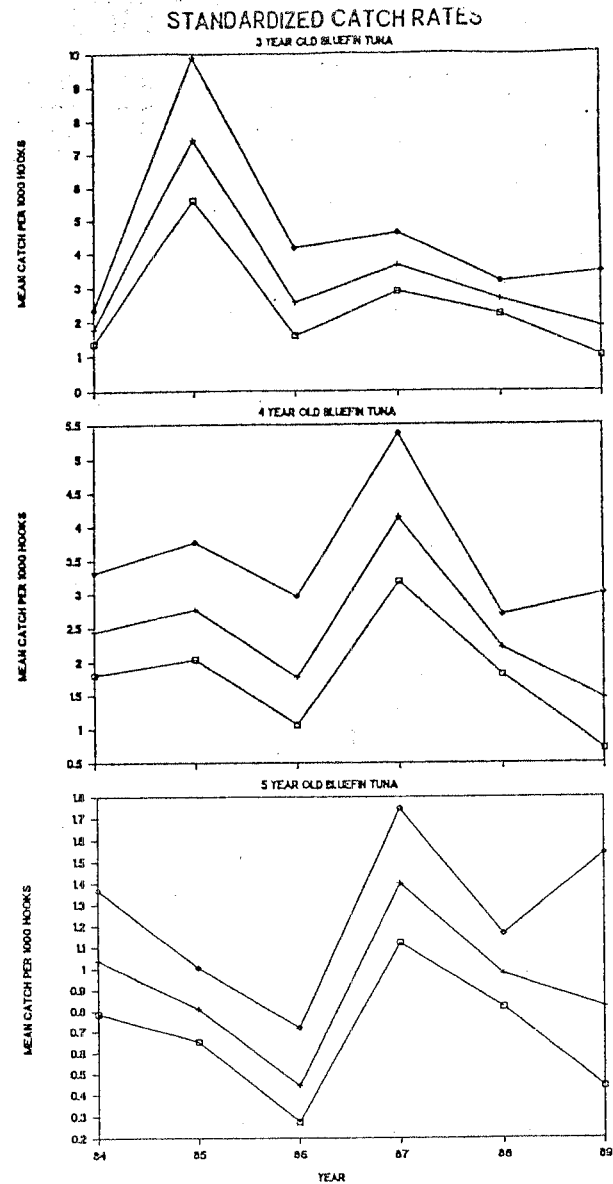


Figure 4. Plots of the standardized mean catch per 1000 hooks developed for 3, 4, and 5 year old bluefin tuna.

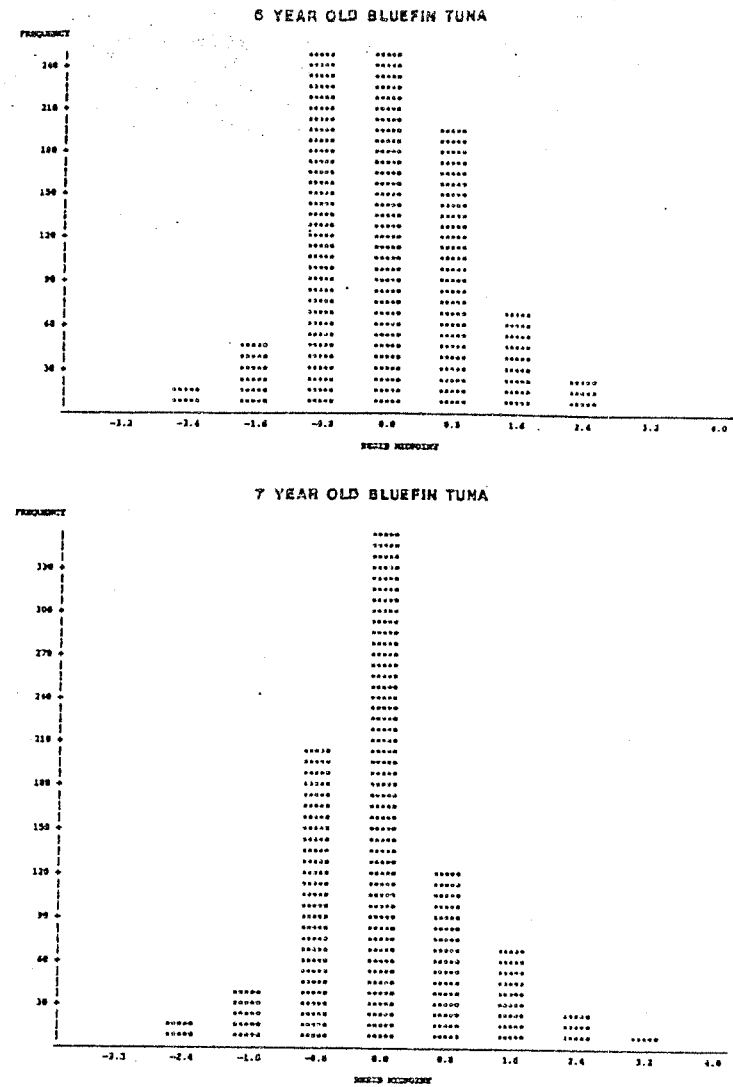


Figure 5. Standardized residual distribution of the final models for 6 and 7 year old bluefin tuna used in the development of standardized catch rates.

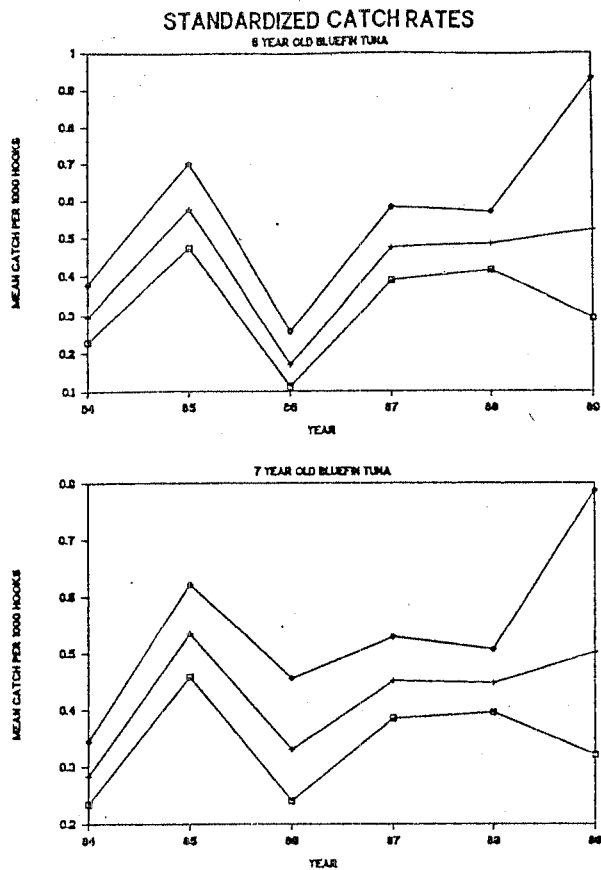


Figure 6. Plots of the standardized mean catch per 1000 hooks developed for 6 and 7 year old bluefin tuna.

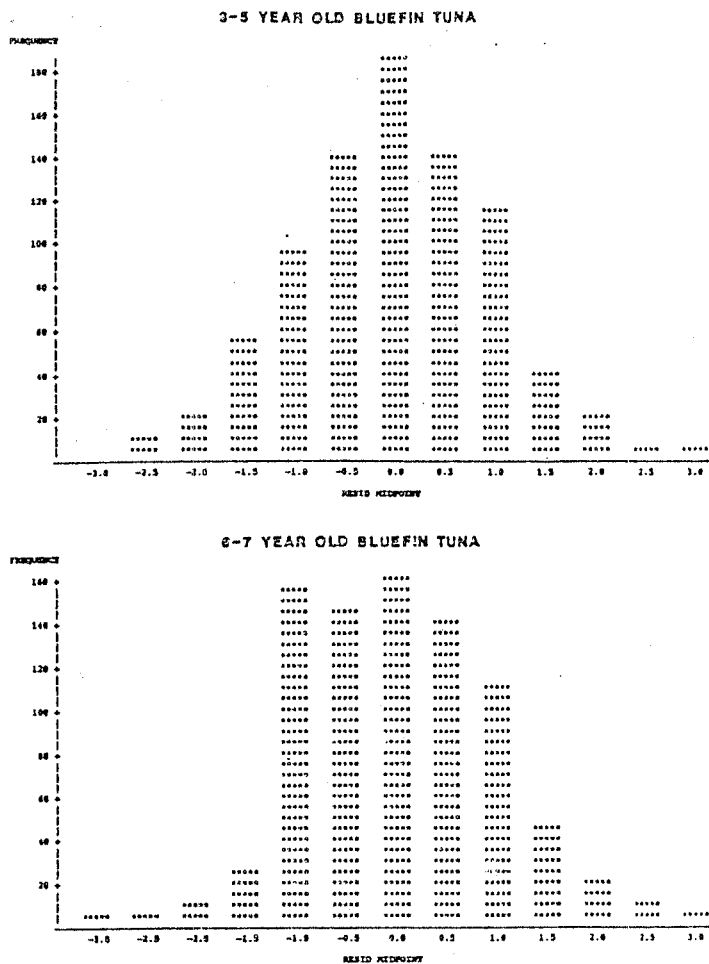


Figure 7. Standardized residual distribution for the final models of 3 to 5 and 6 to 7 year old bluefin tuna age groups used in the development of standardized catch rates.

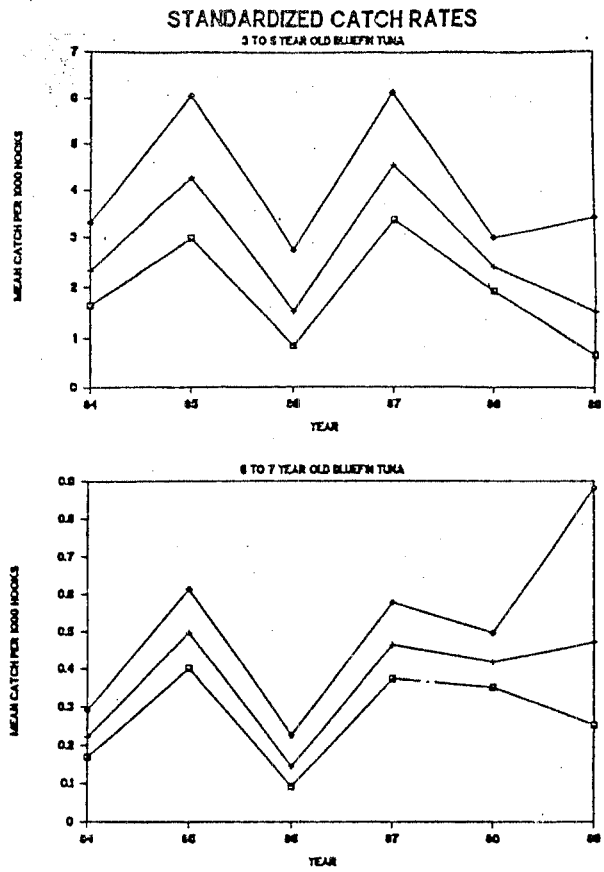


Figure 8. Plots of the standardized mean catch per 1000 hooks developed for 3 to 5 and 6 to 7 year old bluefin tuna age groups.