

**UPDATED STANDARDIZED CATCH RATES FOR BLUEFIN TUNA  
(*THUNNUS THYNNUS*) FROM THE TRAP FISHERY IN THE  
STRAITS OF GIBRALTAR**

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*SUMMARY*

*A General Linear Modeling (GLM) approach to analysis of variance was used to examine bluefin tuna catch rates from the Spanish trap fishery in the Straits of Gibraltar. Standardized catch rates for bluefin tuna were updated for the period 1981-2000.*

*RÉSUMÉ*

*On a utilisé des techniques de Modèle linéaire généralisé (GLM) pour analyser les taux de capture du thon rouge provenant de la pêche de madragues du détroit de Gibraltar. Les taux de capture standardisés pour le thon rouge ont été actualisés pour la période 1981-2000.*

*RESUMEN*

*Se utilizaron técnicas de análisis lineal generalizado (GLM) para analizar la tasa de captura de atún rojo procedente de la pesquería de almadraba del Estrecho de Gibraltar. Se actualizaron las tasas de captura estandarizadas para el período 1981-2000.*

*KEY WORDS*

*Catch/effort, least squares method, abundance, trap fishing.*

## 1. MATERIAL AND METHODS

Data were obtained from the Spanish trap fishery for bluefin tuna in the south of Spain. Information on catches in number of individuals, size composition, effort, and trap characteristics was collected from 1981 to 2000.

A General Linear Modeling (GLM) approach to analysis of variance was used to examine logged catch rates (catch in number of individuals per day of bunt set between consecutive net lifting operations or *matanzas*) for differences among the effects of year, month, and trap.

The general multiplicative model (Gavaris 1980, 1988) used was as follows:

$$\text{Log (CPUE)} = \mu + Y_i + M_j + C_k + M_i * T_k + e_{ijk}$$

where Log : natural logarithm  
 $\mu$  : intercept

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|                   |   |
|-------------------|---|
| CPUE              | : catch rate                              |
| $Y_i$             | : effect of factor year                   |
| $M_j$             | : effect of factor month                  |
| $T_k$             | : effect of factor trap                   |
| $M_j * T_k \dots$ | : interaction term between month and trap |
| $e_{ijk}$         | : error term $N(0, \sigma^2)$             |

Annual abundance indices were obtained from marginal means (least squares mean estimates), adjusted for the GLM statistically significant terms.

## 2. RESULTS

The final model, class level information and F-test are given in **Table 1**. Both factors, month and trap, and corresponding interaction were statistically significant at the 1 % level.  $R^2$  was about 16 %. The distribution of the standardized residuals for the whole model is shown in **Figure 1**.

Standardized annual indices of abundance are shown in **Table 2**. Standardized CPUE with 95 % upper and lower confidence limits are shown in **Figure 2**.

## LITERATURE CITED

- GAVARIS, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. *Can. J. Fish. Aquat. Sci.* 37; pp 2272- 2275.
- GAVARIS, S. 1988. Abundance indices from commercial fishing. Collected papers on stock assessment methods. CAFSAC Res. Doc. 88/61. 167 p.

**Table 1.-** GLM results for bluefin tuna catch rates in number of fish from the Spanish traps in the Straits of Gibraltar.

| The GLM Procedure       |        |                |                |                |             |         |              |         |        |      |      |      |      |      |      |      |
|-------------------------|--------|----------------|----------------|----------------|-------------|---------|--------------|---------|--------|------|------|------|------|------|------|------|
| Class Level Information |        |                |                |                |             |         |              |         |        |      |      |      |      |      |      |      |
| Class                   | Levels | Values         |                |                |             |         |              |         |        |      |      |      |      |      |      |      |
| year                    | 20     | 1981           | 1982           | 1983           | 1984        | 1985    | 1986         | 1987    | 1988   | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|                         |        | 1996           | 1997           | 1998           | 1999        | 2000    |              |         |        |      |      |      |      |      |      |      |
| month                   | 3      | 4              | 5              | 6              |             |         |              |         |        |      |      |      |      |      |      |      |
| trap                    | 4      | 1              | 2              | 3              | 4           |         |              |         |        |      |      |      |      |      |      |      |
| Number of observations  |        |                |                |                |             |         |              |         |        | 1755 |      |      |      |      |      |      |
| Dependent variable:     |        | Incpuen        |                |                |             |         |              |         |        |      |      |      |      |      |      |      |
| Source                  |        | DF             | Sum of Squares |                | Mean Square |         | F Value      |         | Pr > F |      |      |      |      |      |      |      |
| Model                   |        | 30             | 1146.835887    |                | 38.227863   |         | 10.84        |         | <.0001 |      |      |      |      |      |      |      |
| Error                   |        | 1724           | 6081.799613    |                | 3.527726    |         |              |         |        |      |      |      |      |      |      |      |
| Corrected Total         |        | 1754           | 7228.635500    |                |             |         |              |         |        |      |      |      |      |      |      |      |
|                         |        | R-Square       | Coeff Var      |                | Root MSE    |         | Incpuen Mean |         |        |      |      |      |      |      |      |      |
|                         |        | 0.158652       | 68.11650       |                | 1.878224    |         | 2.757370     |         |        |      |      |      |      |      |      |      |
| Source                  |        | DF             | Type I SS      |                | Mean Square |         | F Value      |         | Pr > F |      |      |      |      |      |      |      |
| year                    |        | 19             | 403.4926088    |                | 21.2364531  |         | 6.02         |         | <.0001 |      |      |      |      |      |      |      |
| month                   |        | 2              | 436.3993362    |                | 218.1996681 |         | 61.85        |         | <.0001 |      |      |      |      |      |      |      |
| trap                    |        | 3              | 224.1209100    |                | 74.7069700  |         | 21.18        |         | <.0001 |      |      |      |      |      |      |      |
| month*trap              |        | 6              | 82.8230323     |                | 13.8038387  |         | 3.91         |         | 0.0007 |      |      |      |      |      |      |      |
| Source                  |        | DF             | Type III SS    |                | Mean Square |         | F Value      |         | Pr > F |      |      |      |      |      |      |      |
| year                    |        | 19             | 445.1000103    |                | 23.4263163  |         | 6.64         |         | <.0001 |      |      |      |      |      |      |      |
| month                   |        | 2              | 400.4228360    |                | 200.2114180 |         | 56.75        |         | <.0001 |      |      |      |      |      |      |      |
| trap                    |        | 3              | 100.2498957    |                | 33.4166319  |         | 9.47         |         | <.0001 |      |      |      |      |      |      |      |
| month*trap              |        | 6              | 82.8230323     |                | 13.8038387  |         | 3.91         |         | 0.0007 |      |      |      |      |      |      |      |
| Parameter               |        | Estimate       |                | Standard Error |             | t Value |              | Pr >  t |        |      |      |      |      |      |      |      |
| Intercept               |        | 2.850529574 B  |                | 0.31129071     |             | 9.16    |              | <.0001  |        |      |      |      |      |      |      |      |
| year                    | 1981   | -0.354768227 B |                | 0.46278185     |             | -0.77   |              | 0.4434  |        |      |      |      |      |      |      |      |
| year                    | 1982   | 0.202623727 B  |                | 0.27673087     |             | 0.73    |              | 0.4641  |        |      |      |      |      |      |      |      |
| year                    | 1983   | -0.135383207 B |                | 0.29449456     |             | -0.46   |              | 0.6458  |        |      |      |      |      |      |      |      |
| year                    | 1984   | 0.291267732 B  |                | 0.32244432     |             | 0.90    |              | 0.3665  |        |      |      |      |      |      |      |      |
| year                    | 1985   | -0.253976325 B |                | 0.27831917     |             | -0.91   |              | 0.3616  |        |      |      |      |      |      |      |      |
| year                    | 1986   | -0.773441287 B |                | 0.28419512     |             | -2.72   |              | 0.0066  |        |      |      |      |      |      |      |      |
| year                    | 1987   | -0.609886292 B |                | 0.28429745     |             | -2.15   |              | 0.0321  |        |      |      |      |      |      |      |      |
| year                    | 1988   | -0.066878840 B |                | 0.26761768     |             | -0.25   |              | 0.8027  |        |      |      |      |      |      |      |      |
| year                    | 1989   | -0.275535419 B |                | 0.28268854     |             | -0.97   |              | 0.3298  |        |      |      |      |      |      |      |      |
| year                    | 1990   | -0.160579871 B |                | 0.26608725     |             | -0.60   |              | 0.5463  |        |      |      |      |      |      |      |      |
| year                    | 1991   | -0.568520411 B |                | 0.27458574     |             | -2.07   |              | 0.0386  |        |      |      |      |      |      |      |      |
| year                    | 1992   | -0.626945697 B |                | 0.27565645     |             | -2.27   |              | 0.0231  |        |      |      |      |      |      |      |      |
| year                    | 1993   | -0.786187601 B |                | 0.28357313     |             | -2.77   |              | 0.0056  |        |      |      |      |      |      |      |      |
| year                    | 1994   | -1.280062014 B |                | 0.28834377     |             | -4.44   |              | <.0001  |        |      |      |      |      |      |      |      |
| year                    | 1995   | -0.501441395 B |                | 0.29790696     |             | -1.68   |              | 0.0925  |        |      |      |      |      |      |      |      |
| year                    | 1996   | -0.756355442 B |                | 0.29586143     |             | -2.56   |              | 0.0107  |        |      |      |      |      |      |      |      |
| year                    | 1997   | 0.419787085 B  |                | 0.25547216     |             | 1.64    |              | 0.1005  |        |      |      |      |      |      |      |      |
| year                    | 1998   | 0.261556933 B  |                | 0.28128855     |             | 0.93    |              | 0.3526  |        |      |      |      |      |      |      |      |
| year                    | 1999   | 0.807387678 B  |                | 0.26426031     |             | 3.06    |              | 0.0023  |        |      |      |      |      |      |      |      |
| year                    | 2000   | 0.000000000 B  |                | .              |             | .       |              | .       |        |      |      |      |      |      |      |      |
| month                   | 4      | -0.692269671 B |                | 0.37865093     |             | -1.83   |              | 0.0677  |        |      |      |      |      |      |      |      |
| month                   | 5      | 0.688779781 B  |                | 0.26952616     |             | 2.56    |              | 0.0107  |        |      |      |      |      |      |      |      |
| month                   | 6      | 0.000000000 B  |                | .              |             | .       |              | .       |        |      |      |      |      |      |      |      |
| trap                    | 1      | -1.369065643 B |                | 0.33513942     |             | -4.09   |              | <.0001  |        |      |      |      |      |      |      |      |
| trap                    | 2      | -0.123922888 B |                | 0.30402898     |             | -0.41   |              | 0.6836  |        |      |      |      |      |      |      |      |
| trap                    | 3      | -0.539862211 B |                | 0.32498060     |             | -1.66   |              | 0.0969  |        |      |      |      |      |      |      |      |

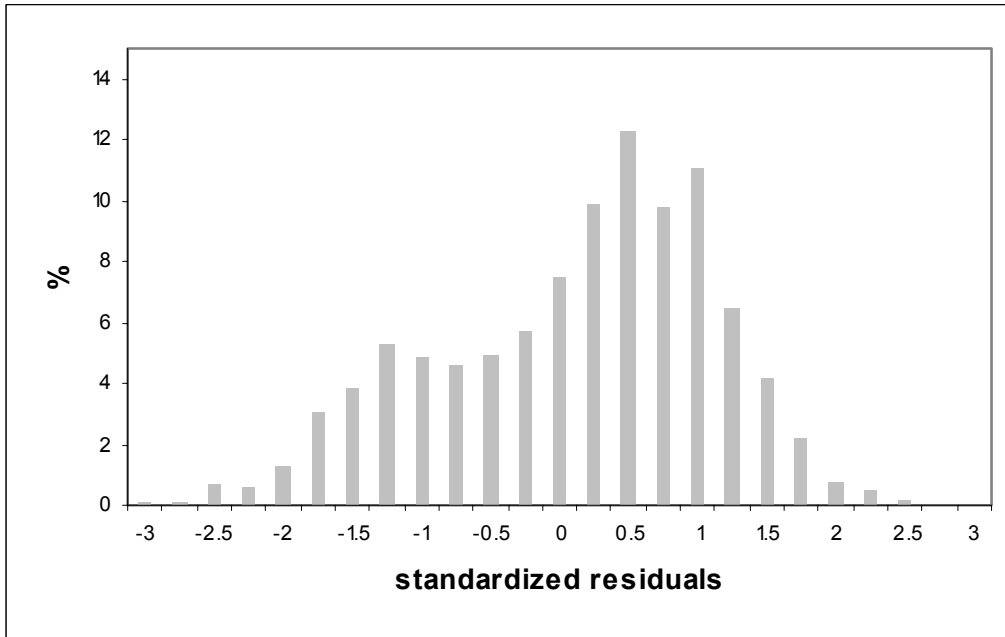
**Table 1.- (cont.)**

|            |     |             |   |            |      |        |
|------------|-----|-------------|---|------------|------|--------|
| trap       | 4   | 0.00000000  | B | .          | .    | .      |
| month*trap | 4 1 | 1.517951872 | B | 0.49239321 | 3.08 | 0.0021 |
| month*trap | 4 2 | 0.067162946 | B | 0.46692438 | 0.14 | 0.8856 |
| month*trap | 4 3 | 0.568487013 | B | 0.47797806 | 1.19 | 0.2345 |
| month*trap | 4 4 | 0.00000000  | B | .          | .    | .      |
| month*trap | 5 1 | 0.470918748 | B | 0.37678297 | 1.25 | 0.2115 |
| month*trap | 5 2 | 0.445840402 | B | 0.34368448 | 1.30 | 0.1947 |
| month*trap | 5 3 | 0.174916546 | B | 0.36281232 | 0.48 | 0.6298 |
| month*trap | 5 4 | 0.00000000  | B | .          | .    | .      |
| month*trap | 6 1 | 0.00000000  | B | .          | .    | .      |
| month*trap | 6 2 | 0.00000000  | B | .          | .    | .      |
| month*trap | 6 3 | 0.00000000  | B | .          | .    | .      |
| month*trap | 6 4 | 0.00000000  | B | .          | .    | .      |

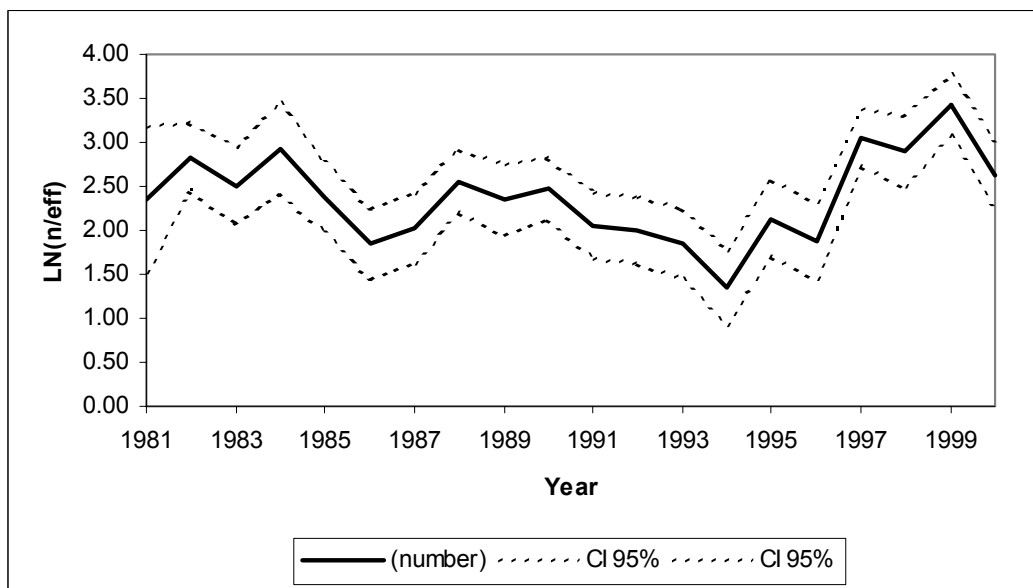
NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

**Table 2.- Standardized CPUE series in number of fish for the Spanish Trap fishery in the Straits of Gibraltar.**

| Year | Least Sqr.<br>Mean | Std.<br>Error | LN CPUE<br>(number) | Lower<br>CI 95% | Upper<br>CI 95% |
|------|--------------------|---------------|---------------------|-----------------|-----------------|
| 1981 | 2.2568             | 0.4197        | 2.3449              | 1.52            | 3.17            |
| 1982 | 2.8142             | 0.1972        | 2.8337              | 2.45            | 3.22            |
| 1983 | 2.4762             | 0.2233        | 2.5011              | 2.06            | 2.94            |
| 1984 | 2.9029             | 0.2596        | 2.9366              | 2.43            | 3.45            |
| 1985 | 2.3576             | 0.2004        | 2.3777              | 1.98            | 2.77            |
| 1986 | 1.8382             | 0.2052        | 1.8592              | 1.46            | 2.26            |
| 1987 | 2.0017             | 0.2057        | 2.0229              | 1.62            | 2.43            |
| 1988 | 2.5447             | 0.1834        | 2.5615              | 2.20            | 2.92            |
| 1989 | 2.3361             | 0.2054        | 2.3571              | 1.95            | 2.76            |
| 1990 | 2.4510             | 0.1794        | 2.4671              | 2.12            | 2.82            |
| 1991 | 2.0431             | 0.1915        | 2.0614              | 1.69            | 2.44            |
| 1992 | 1.9846             | 0.1950        | 2.0037              | 1.62            | 2.39            |
| 1993 | 1.8254             | 0.2078        | 1.8470              | 1.44            | 2.25            |
| 1994 | 1.3315             | 0.2152        | 1.3547              | 0.93            | 1.78            |
| 1995 | 2.1102             | 0.2260        | 2.1357              | 1.69            | 2.58            |
| 1996 | 1.8552             | 0.2238        | 1.8803              | 1.44            | 2.32            |
| 1997 | 3.0314             | 0.1647        | 3.0449              | 2.72            | 3.37            |
| 1998 | 2.8732             | 0.2036        | 2.8939              | 2.49            | 3.29            |
| 1999 | 3.4190             | 0.1779        | 3.4348              | 3.09            | 3.78            |
| 2000 | 2.6116             | 0.2008        | 2.6318              | 2.24            | 3.03            |



**Figure 1.-** Standardized residuals for GLM fit (catch rates in number of fish).



**Figure 2.-** Standardized CPUE series in number of fish for the Spanish BFT Trap fishery in the Straits of Gibraltar. Dashed lines indicate 95% confidence bands.