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# Natural mortality in a Mediterranean sardine population

by

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## 1.- Introduction

*Sardina pilchardus* landed in Castellon and Vinaroz harbours (Spanish Mediterranean coast) belongs to a stock unit described by Larrañeta (1968). This stock is not clearly separated from the one off northern Castellon area and it seems to be independent from the one supporting the southern Castellon fishery. For practical purposes this stock can be regarded as a single unit.

Landings were sampled systematically from 1950 to 1969 in Castellon and from 1956 to 1969 in Vinaroz. Data on age composition fishing effort and catch per unit effort were published in several papers by Larrañeta and Suau, issued in *Investigación Pesquera*.

The sardine populations from Gibraltar to Alicante (SE. of Spain) have some Atlantic characteristics but Castellon sardine population is more similar to those of the rest of the Mediterranean sea (Larrañeta, 1968).

During the night the fishes are concentrated under strong light-sources and catched with a *traiña*, a purse-seine like gear. Larrañeta (1958) found a relationship between the fishing power and the illuminated water volume, expresed by the equation

$$\sqrt[3]{p} = a.\log_e I_o - b$$

where p = fishing power

$I_o$ = light-source intensity

*a* and *b* = constants

This expression has been taken into account to calculate the fishing power of each fishing unit. Annual fishing effort was calculated by two ways: considering the activity of a fishing unit only when landings of sardine caught in previous night took place ("night" effort) or the number of moon months in which the vessel was in the fishing ground ("moon" effort), as the fishing activity is normally carried out according to moon months, stopping during full moon.

2.- Total mortality rates

To estimate the instantaneous rate of total mortality several methods were used in order to test as many relationships with fishing effort as possible. Those methods were the following:

$Z_1$. Comparing logarithms of the catch per unit effort "night" of an annual class in two consecutive years, for ages 2-3, 3-4 and 4-5 and averaging the instantaneous rates belonging to three different annual classes of each particular year (Table 1).

$Z_2$. As in $Z_1$ but using "moon" effort (Table 2).

$Z_3$. Estimating virtual population of each annual class at ages 2, 3 and 4, and calculating the values of Z between ages 2-3 and 3-4, and averaging for each particular year the values belonging to two different annual classes (Table 3).

$Z_4$. Angular coefficient of the regression line between ages 2 and 5+ of the annual catch curve (Table 4).

$Z_5$. Total mortality between ages 3-4 from catch curve, corrected in order to take into account the differences in recruitment for each year-class (Table 5).

$Z_6$. Average total mortality between ages 2-4 from catch curve, corrected in order to take into account the differences in recruitment for each year-class (Table 6).

To estimate $Z_5$ and $Z_6$ the expression (Gulland, 1971):

$$Z = \log \frac{n_t}{n_{t+1}} - \log \frac{N_o}{N'_o}$$

was used, where $n_t$ and $n_{t+1}$ are the c.p.u.e. of two consecutive age groups in a particular year and $N_o$ and $N'_o$ are an index of the size of the recruitments of the corresponding annual classes estimated by adding c.p.u.e. ("night") at ages 0, 1 and 2.

Also the linear formula of Paloheimo (1961) was used to estimate directly $\hat{M}$ and $\hat{q}$ obtaining negative values for $\hat{M}$, thus this method was disregarded.

3.- Estimates of the natural mortality

We have tried to find the best correlation between total mortality and fishing effort in order to get a reliable regression line Z = f.q+M. Table 9 shows the result of a series of those correlations. $Z_1$ and $Z_2$ were calculated by comparing c.p.u.e. in two successives years, t and t+1. These rates were plotted against fishing effort in year t, year t+1 and the average (t, t+1). None of the correlations was really significative ($P<0.05$). The best correlations seem to be o), p), s) and t).

Taylor (1959) has proposed an approach to estimate M using the formula

$$M = \frac{2.996}{A_{0.95}}$$

were $A_{0.95}$ is the age at which the fish reaches 95% of $L_\infty$. According to Larrañeta (1965) the parameters of the Bertalanffy's equation for the Castellon sardine are

$$L_\infty = 203.4 \text{ mm}$$
$$K = 0.3065$$
$$t_o = -1.54 \text{ years}$$

Beverton (1963) suggests that in sprat, Sardina pilchardus and engraulids the ratio M/K is aproximately 1.6.

Rikhter and Efanov (1976) have proposed an approach using the empirical equation

$$Y = \frac{1.521}{x^{0.72}} - 0.155$$

where Y (=M) is the natural instantaneous mortality rate and x is the age at massive maturation. Larrañeta (1976) estimates that massive maturation occurs in Castellon sardine at age 2 years.

Summarizing, the estimates values for M according to the different methods used are the following:

i) Regression corresponding correlation o) . . . . 1.16
ii) Regression corresponding correlation p) . . . . 0.96
iii) Regression corresponding correlation s) . . . . 1.08
iv) Regression corresponding correlation t) . . . . 0.92
v) Taylor's approach . . . . . . . . . . . . . . . . 0.36
vi) Beverton's rate M/K . . . . . . . . . . . . . . . 0.49
vii) Rikhter and Efanov's approach . . . . . . . . . 0.77

4.- Discussion

The most reliable method to estimate natural mortality is the regression between fishing effort and total mortality, with the condition of a constant coefficient of catchability, but as it is shown in table 9 none of the correlations between total mortality and effort has a ramdon probability minor than 0.05. However estimates of M from these regressions are relatively closed, ranging from 0.92 to 1.16.

Values for M of 0.36 and 0.49 seem to be too low if we compare them with the previous estimates. However the value of 0.77, obtained from the Rikhter and Efanov's approach, seems to be more reliable and in the neighbourhood of the estimations obtained from regression lines.

A question arises; Z values were calculated for fully recruited ages, 2 years and more. Nevertheless tables 1 to 6 show calculated Z values between 0.8 and 0.9, that is to say, minor than estimates of M by regression lines, and the fishing activity has been always important. Although admiting that an important variance in the estimates may exist it seems that values for M more than 0.9 are perhaps overestimations. Somehow or other, natural mortality seems to be high in Castellon sardine and M values between 0.8 and 1.0 seem to be the most suitable ones.

5.- Summary

With data on age composition and fishing effort of the Castellon sardine (Sardina pilchardus) population from 1956 to 1969 regression lines between total mortality and effort are calculated. Also approaches of Taylor, Beverton and Rikhter and Efanov to estimate M are used. Natural instantaneous mortality rate seems to be high and in the range of 0.8 to 1.0.

6.- Résumé

On a calculé des régressions entre la mortalité totale et l'effort de pêche dans la population de sardine (Sardina pilchardus) de Castellon avec des données sur la composition en âge et l'effort depuis 1956 jusqu'à 1969. Nous avons employé aussi les formules de Taylor, Beverton et Rikhter et Efanov pour l'estimation de M. Le coefficient instantané de mortalité naturelle est environ de 0.8 à 1.0.

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Table 1.- $Z_1$. Average mortality rates between two years and for age groups 2-5+. Effort "night".

| Years | Z | Years | Z | Years | Z |
|---|---|---|---|---|---|
| 1956-1957 | 0.79 | 1961-1962 | 1.07 | 1965-1966 | 0.72 |
| 1957-1958 | 1.92 | 1962-1963 | 0.94 | 1966-1967 | 0.92 |
| 1958-1959 | 1.41 | 1963-1964 | 1.27 | 1967-1968 | 2.02 |
| 1959-1960 | 1.76 | 1964-1965 | 1.18 | 1968-1969 | 1.92 |
| 1960-1961 | 1.70 | | | | |

Table 2.- $Z_2$. Average mortality rates between two years and for age groups 2-5+. Effort "moon".

| Years | Z | Years | Z | Years | Z |
|---|---|---|---|---|---|
| 1956-1957 | 0.82 | 1961-1962 | 0.80 | 1965-1966 | 0.80 |
| 1957-1958 | 1.97 | 1962-1963 | 1.12 | 1966-1967 | 1.12 |
| 1958-1959 | 1.44 | 1963-1964 | 1.29 | 1967-1968 | 1.99 |
| 1959-1960 | 1.81 | 1964-1965 | 1.43 | 1968-1969 | 2.08 |
| 1960-1961 | 1.81 | | | | |

Table 3.- $Z_3$. Total mortality from virtual population.

| Year | Z | Year | Z | Year | Z |
|---|---|---|---|---|---|
| 1956 | 0.99 | 1960 | 1.73 | 1964 | 1.86 |
| 1957 | 2.05 | 1961 | 1.04 | 1965 | 0.89 |
| 1958 | 1.42 | 1962 | 1.23 | 1966 | 1.08 |
| 1959 | 1.86 | 1963 | 1.39 | 1967 | 1.43 |
| | | | | 1968 | 1.63 |

Table 4.- $Z_4$. Total mortality from catch curves.

| Year | Z | Year | Z | Year | Z |
|---|---|---|---|---|---|
| 1956 | 1.33 | 1961 | 1.51 | 1966 | 1.35 |
| 1957 | 1.42 | 1962 | 1.55 | 1967 | 1.02 |
| 1958 | 1.54 | 1963 | 1.33 | 1968 | 1.57 |
| 1959 | 1.60 | 1964 | 1.35 | 1969 | 1.62 |
| 1960 | 1.40 | 1965 | 0.88 | | |

Table 5.- $Z_5$. Total mortality between ages 3 and 4 from catch curves. Corrected.

| Year | Z | Year | Z | Year | Z |
|---|---|---|---|---|---|
| 1956 | 1.78 | 1961 | 2.72 | 1966 | 1.91 |
| 1957 | 2.13 | 1962 | 2.55 | 1967 | 1.12 |
| 1958 | 1.26 | 1963 | 0.98 | 1968 | 2.12 |
| 1959 | 2.40 | 1964 | 1.40 | 1969 | 1.79 |
| 1960 | 1.96 | 1965 | 0.90 | | |

Table 6.- $Z_6$. Total mortality between ages 2 and 4 from catch curves. Corrected.

| Year | Z | Year | Z | Year | Z |
|---|---|---|---|---|---|
| 1956 | 1.49 | 1961 | 1.76 | 1966 | 1.38 |
| 1957 | 1.31 | 1962 | 1.69 | 1967 | 1.15 |
| 1958 | 1.42 | 1963 | 1.27 | 1968 | 1.45 |
| 1959 | 1.45 | 1964 | 1.06 | 1969 | 1.52 |
| 1960 | 1.64 | 1965 | 0.88 | | |

Table 7.- Fishing effort "night"

| Year | f | $\bar{f}$ | Year | f | $\bar{f}$ | Year | f | $\bar{f}$ |
|---|---|---|---|---|---|---|---|---|
| 1956 | 5588 | | 1961 | 6149 | | 1966 | 2342 | |
| | | 5374 | | | 7093 | | | 4220 |
| 1957 | 5159 | | 1962 | 8037 | | 1967 | 2586 | |
| | | 5218 | | | 7562 | | | 2792 |
| 1958 | 5277 | | 1963 | 7087 | | 1968 | 2997 | |
| | | 5660 | | | 6537 | | | 3422 |
| 1959 | 6042 | | 1964 | 5987 | | 1969 | 3847 | |
| | | 6584 | | | 4656 | | | |
| 1960 | 7125 | | 1965 | 3325 | | | | |
| | | 6638 | | | 4589 | | | |

Table 8.- Fishing effort "moon".

| Year | f | $\bar{f}$ | Year | f | $\bar{f}$ | Year | f | $\bar{f}$ |
|---|---|---|---|---|---|---|---|---|
| 1956 | 516 | | 1961 | 756 | | 1966 | 378 | |
| | | 534 | | | 756 | | | 440 |
| 1957 | 551 | | 1962 | 756 | | 1967 | 503 | |
| | | 542 | | | 780 | | | 537 |
| 1958 | 533 | | 1963 | 804 | | 1968 | 572 | |
| | | 581 | | | 746 | | | 725 |
| 1959 | 627 | | 1964 | 638 | | 1969 | 878 | |
| | | 704 | | | 590 | | | |
| 1960 | 780 | | 1965 | 492 | | | | |
| | | 768 | | | 435 | | | |

Table 9.- Correlations between total mortality and fishing effort.

| | Total mortality | Effort | r | f.d. | P |
|---|---|---|---|---|---|
| a) | $Z_1$ | night t | 0.293 | 9 | 0.3-0.4 |
| b) | $Z_1$ | night t+1 | 0.390 | 9 | 0.2-0.3 |
| c) | $Z_1$ | night t-t+1 | 0.215 | 9 | 0.5-0.6 |
| d) | $Z_1$ | moon t | 0.220 | 9 | 0.5-0.6 |
| e) | $Z_1$ | moon t+1 | 0.319 | 9 | 0.3-0.4 |
| f) | $Z_1$ | moon t-t+1 | 0.328 | 9 | 0.3-0.4 |
| g) | $Z_2$ | night t | 0.248 | 9 | 0.4-0.5 |
| h) | $Z_2$ | night t+1 | 0.188 | 9 | 0.5-0.6 |
| i) | $Z_2$ | night t-t+1 | 0.132 | 9 | 0.7-0.8 |
| j) | $Z_2$ | moon t | 0.149 | 9 | 0.6-0.7 |
| k) | $Z_2$ | moon t+1 | 0.215 | 9 | 0.5-0.6 |
| l) | $Z_2$ | moon t-t+1 | 0.224 | 9 | 0.5-0.6 |
| m) | $Z_3$ | night | 0.221 | 11 | 0.4-0.5 |
| n) | $Z_3$ | moon | 0.218 | 11 | 0.4-0.5 |
| o) | $Z_4$ | night | 0.379 | 12 | 0.1-0.2 |
| p) | $Z_4$ | moon | 0.463 | 12 | 0.05-0.1 |
| q) | $Z_5$ | night | 0.324 | 12 | 0.2-0.3 |
| r) | $Z_5$ | moon | 0.168 | 12 | 0.5-0.6 |
| s) | $Z_6$ | night | 0.456 | 12 | 0.1-0.2 |
| t) | $Z_6$ | moon | 0.447 | 12 | 0.1-0.2 |