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ESTIMATE OF SPAWNING BIOMASS OF ANCHOVY, *ENGRAULIS ENCRASICOLUS*, IN THE EASTERN PART OF ADRIATIC FROM 1989 TO 1990 BY MEANS OF EGG SURVEYS

SZACOWANIE BIOMASY PO PULACJI TARŁOWEJ SARDELI, *ENGRAULIS ENCRASICOLUS*, NA PODSTAWIE ILOŚCI ZŁOWIONEJ IKRY WE WSCHODNIEJ CZĘŚCI ADRIATYKU W OKRESIE 1989–1990

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The objective of the study was to present the results of anchovy stock assesment for one period (1989–1990) of surveys and to estimate maximum sustainable yield on the basis of the estimated spawning biomass. Anchovy stock has not been fully exploited during that period but was decreasing and affected by long term fluctuations in biomass.

INTRODUCTION

The implementation of measures of proper management of living resources sequires the knowledge of their stock and technology of their renewal. In that way the part that an be removed by catch not threatening the stock. Therefore calculation of maximum sustainable yield requires the knowledge of the number of individuals and biomass of populations of exploited fish species as well as the variations of these two parameters in space and time. Lack of the knowledge of these facts makes impossible the determination of the capacity of fishing fleet and fishing techniques, on the one hand. On the other hand, schematization of fishing intesity that will yield optimum economic effects, not causing overfishing would be impossible. Since the past years have witnessed an intensification of the efforts to promate Croatian fishing fleet, stock assessment of Adriatic commercially important species is needed ever more.

Anchovy, *Engraulis encrasicolus* (Linnaeus, 1785), belongs to the small pelagic fish which are of relatively great economical importance in the eastern part of the Adriatic.

Several attempts have been done up to now to estimate the biomass of this fish, so it is relatively strange that most of the past estimates were done by direct methods, either by echosurveys (Azzali, 1980; Azzali et al., 1983; Kačić, 1983), or by egg surveys (Štirn, 1969; Karlovac et al., 1974; Piccinetti et al., 1979; Piccinetti et al. 1981; Regner et al. 1985). The estimates obtained by other methods are scarce (Grubišić et al., 1974; Levi et al., 1983).

The aim of this paper is to present the results of anchovy stock assessment for an entire period of surveys (1989–1990) to estimate maximum sustainable yield on the basis of the estimated spawning biomass.

MATERIAL AND METHODS

The plankton was sampled by double–oblique hauls of Bongo–20 plankton net equipped with the flow and depthmeters. The anchovy eggs from each net were sorted separately, and the mean number from both cylindres was calculated for every haul. The net was towed 10–20 minutes at a speed of 1.5–2 knots. The ichthyoplankton samples were taken from the 46 stations along 10 profiles, placed transversally from the Italian coast to the edge of the Croatian territorial waters, during the period 14–20 August 1989 and from 31 station along 7 profiles during the period 30 July – 4 August 1990 (Fig. 1).

At every station the temperature of the sea water was recorded at 1 m depth. These data were used for estimations of the duration of the egg stage from spawning to hatching. During sorting, all anchovy eggs were divided in five previously defined embryonic stages.

As there as not more than one cruise per spawning season, the intesity of spawning during the entire spawning seasons was monitored at 3 fixed stations in the vicinity of Split:

a) Kaštela Bay (43°31' N 16°22' E)
b) Cape Pelegrin – island Hvar (43°12' N 16°19' E)
c) Cape Stončica – island Vis (43°00' N 16°20' E).

The least frequency of sampling at these stations was once a month. The curves of spawning intesity obtained from these stations were used for estimations of the total number of eggs produced during the spawning season.

Fig. 1. Distribution of profiles and stations

The stock size was estimated from the expression:

$$B = \frac{E}{F_r}(1 + R) \qquad (1)$$

where B is the estimated biomass of spawners, E estimated total number of eggs produced during the spawning season over the surveyed area, F_r relative fecundity, and R sex ratio. Although it is known that there is relatively high variability between the ratio of males and females of the anchovy, their ratio in general is equal to 1 (Varangolo, 1967; Sinovčić, 1978; Piccinetti et al., 1979).

Surface of the investigated area during the first cruise was 57725.5 km^2 and during the second cruise was 29972.2 km^2.

RESULTS AND DISCUSSION

The number of eggs under the unit of surface was estimated using the formula:

$$Y = \frac{X}{S \frac{L}{d}} \qquad (2)$$

where Y is the number of eggs under 1 m^2, X number of eggs in the sample, S surface of the net, L distance towed, while d is the maximum depth attained.

The number of eggs produced under the m^2 per day was estimated using Tanaka's (1973) transformed equation:

$$N = \frac{Y}{\frac{1}{m}(1 - e^{-mD})} \qquad (3)$$

where N is the number of eggs produced under 1 m^2 per day, Y number of eggs estimated from the equation (2), while m and D are instantaneous mortality rate and incubation time of eggs in days, respectively.

To avoid the influence of contagious distribution of fish eggs on the estimate of the mean number of eggs, the post stratification for every survey was made by measuring surfaces of the areas within the isometric lines of the folowing orders of magnitude:

0 –	
0.1 –	0.99
1.0 –	9.9
10.0 –	99.9
100.0 –	999.9
>1000.0	

Consequently, the mean number of eggs produced under 1 m^2 per day weighed by the surface of strata (Table 1) can be estimated from the equation:

$$\bar{N}_c = \frac{1}{\sum_{i=1}^{a} P_i} \sum_{i=1}^{a} P_i \frac{\bar{Y}_i}{\frac{1}{\bar{m}}(1 - e^{-\bar{m}_i \bar{D}_i})} \qquad (4)$$

where $\bar{m}_i$ and $\bar{D}_i$ are mean instantaneous mortality rates and mean incubation times within i–th stratum.

Table 1

The mean numbers of eggs spawned under 1 m^2/day during the cruises, their variances and 95% confidence limits

Cruise	$\bar{N}_c$	S_c^2	$\bar{N}_c + to.5\ S_{\bar{N}}$	$\bar{N}_c + to.5\ S_{\bar{N}}$
1989	38.17	17520.52	61.21	13.44
1990	247.62	669563.3	422.91	100.47

The incubation time, from fertilization to hatching, as a function of temperature, for the anchovy eggs was estimated from the equation whose parameters had been obtained from observations on temperature – time relationship of embryonic development of anchovy eggs under experimental conditions (Regner, 1979/1985):

$$D = \frac{1}{1.012896} (1 + e^{4.914322-0.257451T}) \qquad (5)$$

where D is the incubation time in days and T temperature in °C. The mean incubation time was 1.223851 days for the first and 1.288729 days for the second cruise.

Total number of eggs spawned per day over the surveyed area (Table 2), when weighed means are used will be:

$$E = \bar{N}_c \times P_{tot} \qquad (6)$$

To estimate total number of eggs produced during the spawning season, E_c has to be integrated over the curve of spawning intesity (Fig. 2). To obtain total numbers of eggs produced during every spawning season (E), the method of planimetry was used. The surface obtained by measuring the area under the spawning curve which was covered by cruise was divided by the surface under the entire curve. Estimated total number of eggs produced during the spawning season and their confidence limits are shown in Table 3.

Table 2

Estimated numbers of eggs spawned per day over the surveyed area, and their 95% confidence limits

Cruise	E_c	$E_c + .05$	$E_c - .05$
1989	$2.012266 x 10^{12}$	$3.227157 x 10^{12}$	$7.088213 x 10^{11}$
1990	$7.421713 x 10^{12}$	$1.267574 x 10^{13}$	$3.011245 x 10^{12}$

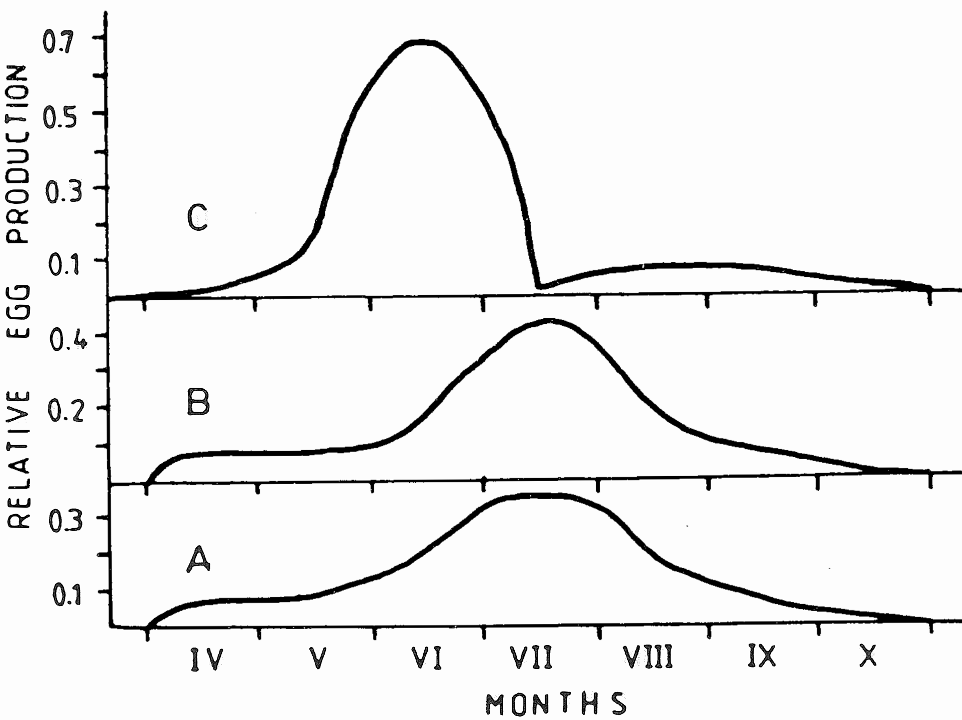

Fig. 2. The general curve of spawning intesity of the anchovy; A = mean; B = upper 95% confidence limit; C = lower 95% confidence limit

Table 3

Estimated total numbers of eggs produced during the spawning seasons and their confidence limits

Cruise	E	E + 0.5	E − 0.5
1989	3.644108×10^{14}	6.549088×10^{14}	4.018555×10^{14}
1990	6.087302×10^{14}	1.129675×10^{16}	3.123543×10^{14}

The biomass was estimated by substituting of values of E and F_r in the equation (1), while the confidence limits were estimated by the use of $E_{\pm 0.5}$ values from Table 3. The results obtained are shown in Table 4. The data on relative fecundity obtained during the investigations in the year 1976 were used (Piccinetti et al., 1979). According to these data the relative fecundity is $F_r = 1299$. The relative fecundity of the anchovy seems to be relatively stable, since the results obtained in 1976 are practically akin to those of Varangolo (1967). This indicates that the relative fecundity, as a relative by stable factor, cannot cause great errors of biomass estimates from statistical point of view. But, there is a problem which is not biologically clear enough. Namely, anchovies are serial spawners, and in the ovaries there were always found three to four batches of oocytes of different sizes, which in total gave the value F_r of 1 299 eggs per gram of female. It can be assumed that the number of batches might be greater than four. This is very probable, because in the case of northern anchovy (*Engraulis mordax* Girard) it was found that females spawned every 6–8 days during the peak of spawning season (Hunter and Goldberg, 1980). If the anchovy in Adriatic spawns in the similar way, the error of biomass estimate can be great. Because of that the future very careful analyses of anchovy's fecundity are indispensable, but for this moment it was assumed that obtained value of F_r is reliable.

Table 4

Biomass of anchovy in the eastern part of Adriatic for period 1989–1990

Year	Biomass (tons)	Confidence limit ($P<0.05$)	
		lower	upper
1989	139 134	49 005	223 134
1990	232 418.7	94 300.29	369 954

In this paper Schaefer's (1954) model, modified by Gulland (1971), was used, which assumes that:

$$MSY = X\,M\,B_0 \qquad (6)$$

where MSY is the maximum sustainable yield, M natural mortality coefficient, B_0 virgin biomass, and X a constant. In that estimate the approximative value of M was found to be 0.65 for anchovy (Sinovčić, unpublished data).

Calculating the value of X as suggested in Gulland (1971), it was found that X varies between 0.38 and 0.87 with the mean of 0.51.

Substituting the values of X and M, as well as the estimated spawning biomass (instead of B_0), in equation (1), the maximum sustainable yield can be obtained for each year. The results are:

Year	MSY ($\bar{B}_{min}$)	MSY ($\bar{B}$)
1989	16 245.157	46 122.921
1990	31 260.546	77 046.799

The catch of anchovy in tons, on the eastern part of the Adriatic, was:

Year	Anchovy catch in tons
1988	374
1989	367
1990	740
1991	696

A comparison of the estimates of MSY, even those obtained for lower 95% confidence limits of biomass estimates ($\bar{B}_{min}$), and annual catches show that anchovy stock was not been fully exploited during the years 1989–1990.

Finally, it should be noted that anchovy stock in the Adriatic has been decreasing and affected by long term fluctuations in biomass not related to fishing. It is known that these changes are generally associated with insidious changes in catchability which may lead to overfishing, especially during the years of decreasing biomass. For that reason, continuous monitoring of anchovy biomass and careful analysis of its population dynamics is necessary.

CONCLUSIONS

The estimates of the biomass of the anchovy for the period from the year 1989 to 1990 were made. Anchovy stock was not fully exploited during that period. It should be noted that anchovy stock has been decreasing and affected by long term fluctuations in biomass not related to fishing. Continuous monitoring of anchovy biomass and careful analysis of its population is needed.

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SZACOWANIE BIOMASY POPULACJI TARŁOWEJ SARDELI *ENGRAULIS ENCRASICOLUS* NA PODSTAWIE ILOŚCI ZŁOWIONEJ IKRY WE WSCHODNIEJ CZĘŚCI ADRIATYKU W OKRESIE 1989–1990

STRESZCZENIE

Dla prowadzenia środków prawidłowego planowania rozwoju rybołówstwa potrzebne jest poznawanie zasobów rybnych które mamy do dyspozycji i które mogą być dostępne do eksploatacji. W tym celu do określenia największego dopuszczonego połowu jest niezbędnie poznawanie biomasy populacji eksploatowanych gatunków ryb, jak również i zmian zachodzących w stadach ryb w przestrzeni i czasie.

Sardela *Engraulis encrasicolus* jest przedstawicielem rodziny *Engraulidae* i należy do drobnych ryb pelagicznych, które mają duże znaczenie gospodarcze na wschodnich wybrzeżach Adriatyku, a w szczególności w rybołówstwie chorwackim, ponieważ dzięki połowom tych gatunków ryb rozwinęło się na wybrzeżu adriatyckim silnie przetwórstwo rybne.

Celem niniejszych badań, było oszacowanie biomasy sardeli na podstawie ilości złowionej ikry w planktonie za okres 1989–1990 roku, jak również obliczenie największego dopuszczalnego połowu na podstawie oszacowanej biomasy populacji tarłowej. Oszacowana biomasa dla 1989 roku wynosiła 139 134 ton, a dla 1990 roku 232 418.7 ton. Porównaniem obliczonych wyników największego dopuszczonego połowu z faktycznymi wynikami połowu sardeli wynika, że stado sardeli w tym czasie nie było adekwatnie eksploatowane.

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