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STOCK ASSESSMENT OF THE ADRIATIC ANCHOVY (*ENGRAULIS ENCRASICOLUS* L.) USING EGG SURVEYS

OCENA STADA SARDELI (*ENGRAULIS ENCRASICOLUS* L.) W ADRIATYKU NA PODSTAWIE ILOŚCI IKRY W PLANKTONIE

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The results of anchovy stock assessment during surveys in periods 1976–1984 and 1989–1990 are given. The influence of the curves of spawning intensity on the error in stock assessment is also discussed. During the periods of surveys it was observed that anchovy stock was decreasing. Estimates using the batch fecundity method show that anchovy stocks were highly overestimated because their fecundity was underestimated. It is obvious that in future surveys in the Adriatic, the batch fecundity methods has to be applied.

INTRODUCTION

Anchovy stock assessment using egg and/or larva surveys are based on the fact that the number of eggs produced by the fish population during the spawning season is proportional, to some extent, to the weight of the mature part of population (Beverton and Holt, 1957), and that it can be expressed by the equation:

$$E = F_r B R \quad (1)$$

where E is the number of eggs produced, F_r is the relative fecundity, B is the biomass of the mature of population, while R is the sex ratio. From the early sixties on, the number of fish species whose stocks were estimated using egg and larva surveys was increasing exponentially.

The first attempt of stock assessment using egg surveys in the Adriatic was made by Štirn (1969), who estimated that anchovy biomass in the northern Adriatic was 250 000 tons in the year 1965. Later Karlovac et al. (1974) estimated that anchovy

biomass in the Adriatic as a whole can reach 190 000 tons. But, in neither of these assessments were taken into consideration all the parameters necessary to be used in this method.

From 1976 the sampling methods are standardized and all parameters needed for fish stock assessment, as far as the fish eggs are concerned, are taken into account. All results can be found in the papers: Piccinetti et al. (1979), Piccinetti et al. (1979a), Piccinetti et al. (1980), Piccinetti et al. (1981), Regner et al. (1985).

The aim of this paper is to present the results of anchovy stock assessment for periods of surveys (1976–1984, 1989–1990) and to discuss the influence of the curves of spawning intesity on the error in stock assessment.

MATERIALS AND METHODS

The systematic anchovy egg surveys were made at the area which covered northern and middle Adriatic, from the gulf of Venice and Trieste, up to line connecting cape Gargano with the cape Ostra at the entrance of Boka Kotorska bay. The surface of this area was 101 219 km^2. Eleven transects connecting Croatian and Italian coast were distributed over the survey area, with the maximum number of 86 stations (Fig. 1).

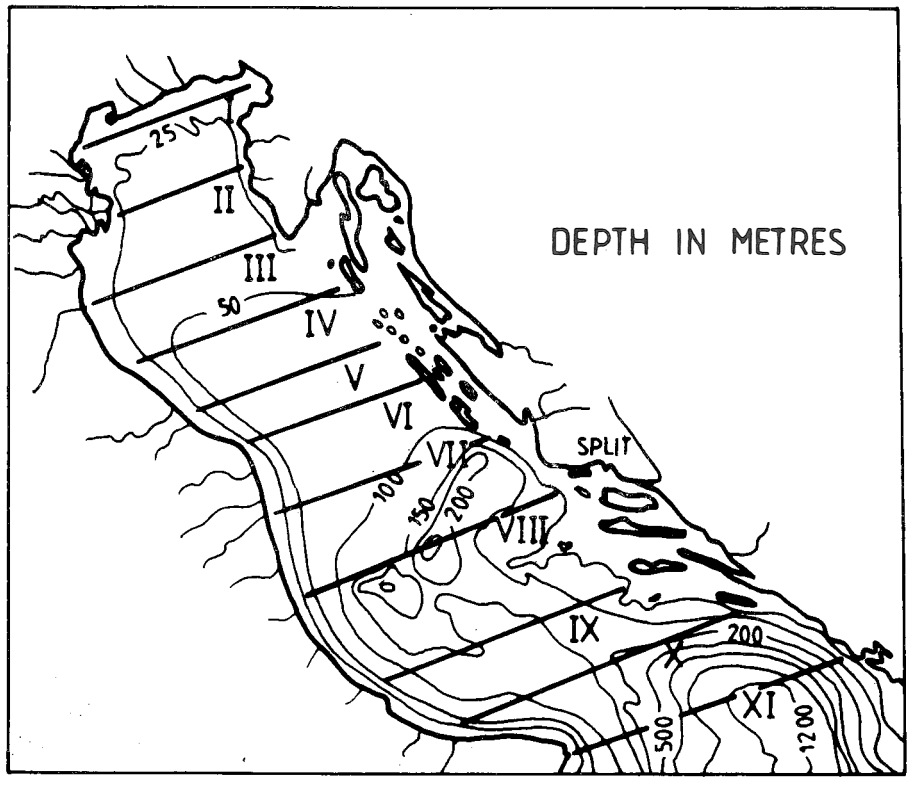

Fig. 1. Distribution of transects over the surveyed area

Anchovy eggs were sampled with the BONGO-20 plankton net, consisting of two cylindres of 20 cm diameter each. One cylinder was equipped with the net of 333 μm, while the other had the net of 250 μm mesh size. At each station the net was towed obliquely at a speed of 1.5–2.0 knots. At the stations where depth did not exceed 60 m, the net was lowered up to about 5 m above the bottom, and at the deeper stations net was towed up to the depth of 60 m. After the sorting of plankton samples, anchovy eggs were classified into five developmental stages, A, B, C, D and E for the estimate of their age. The incubation time, from fertilization to hatching, as a funktion of temperature, for the anchovy eggs was estimated from the equation whose parameters have been obtained from observations on temperature-time relationship of embryonic development of anchovy eggs under experimental conditions (Regner, 1979/1985):

$$D = \frac{1}{1.012896}(1 + e^{4.914322 - 0.257451T}) \qquad (2)$$

where D is incubation time in days and T temperature in °C.

Estimates of anchovy biomass in the Adriatic were made using total relative fecundity, or the total number of eggs per unit weight of female spawned during the spawning season. From data reported by Varangolo (1967) and Piccinetti et al. (1979) it was found that 3–4 lots of oocytes were presented in the anchovy ovaries, and mean relative fecundity was estimated to be $F_r = 1.299$. If relative fecundity is used, the total number of eggs produced during the spawning season ($\bar{E}$) has to be estimated. It was decided to monitor intesity of spawning at the permanent stations in the vicinity of Split. The relative intesity of spawning was estimated, and the curves of spawning intensity were constructed for every spawning season, as these curves were mostly polymodal, mean number of eggs/m^2/day during the surveys was integrated over the curves of spawning intesity using the measuring of the surfaces under the spawning curves which were covered by surveys using planimetry. The surface obtained by measuring the area under the spawning curve which was covered during the survey was divided by the surface under the entire curve to obtain correction:

$$r = \frac{s}{S}$$

The number of eggs which was produced during the period of survey was divided by the value of r and multiplied with the surface of surveyed area. In this way was estimated total number of eggs spawned during the spawning season.

The sex ratio of anchovy in the Adriatic, although it can have relatively high variability, in general is equal to 1 (Mužinič, 1954; Varangolo, 1967; Sinovčić, 1978; Piccinetti et al., 1979). So, the mean value of R is 0.5.

Substituting the values of $\bar{E}$, F_r and R in the rearranged equation (1) the biomass was estimated.

In the case of anchovy the standard error of relative fecundity was not taken into consideration, but the possible variabilities of the spawning curves were included into

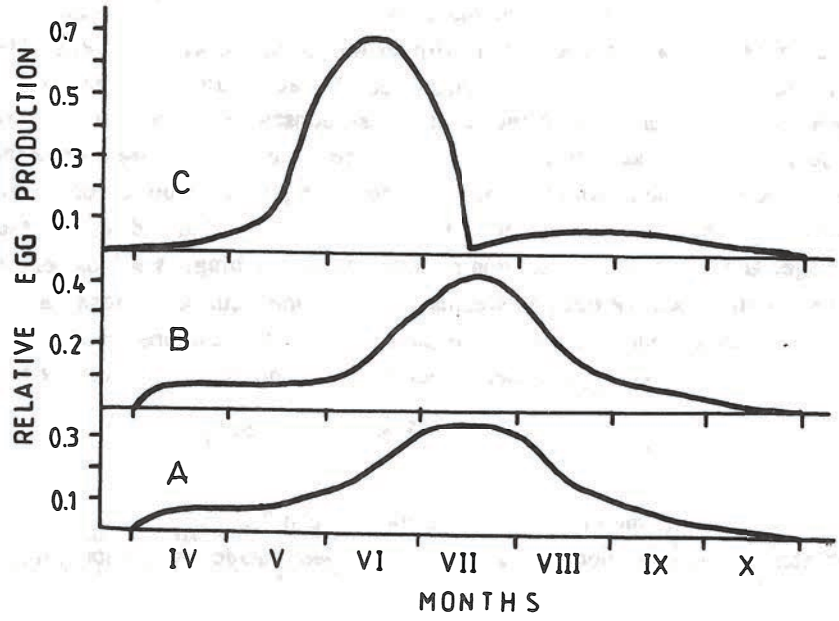

Fig. 2. The general curve of spawning intensity of the anchovy, A = mean; B = upper 95% confidence limit; C = lower 95% confidence limit

the confidence limits of estimates (Regner et al., 1985). For that purpose ther were calculated mean values of eggs spawned under the m^2 per day for every month from April to October for a long series of spawning seasons. The corresponding standard errors were also calculated. Using the t-test procedures the upper and lower limits of 95% confidence levels were estimated (Fig. 2).

RESULTS

The following results were obtained:

Anchovy			
		95% confidence limits	
Year	Biomass (Tons)	Upper	Lower
1976	1 095 919	9 459 969	886 046
1977	5 676 674	8 121 632	769 053
1978	4 076 982	31 670 516	3 193 225
1979	1 858 352	13 736 516	1 447 290
1980	2 494 226	15 688 882	1 948 549
1981	1 264 203	15 236 336	341 031
1982	1 939 954	23 494 996	1 441 878

Anchovy			
		95% confidence limits	
Year	Biomass (Tons)	Upper	Lower
1983	1 336 743	13 005 389	529 176
1984	1 391 224	1 858 353	952 578
1989[1]	139 134	223 134	49 005
1990[2]	232 418	369 954	94 300

[1] In 1989 the survey was performed only at the eastern half of the survey area, at the surface of 52 726 km^2.

[2] In 1990 the survey was performed only at the eastern half of the survey area, at the surface of 29 972.2 km^2. Along the eastern Adriatic coast concentrations of anchovy schools are much smaller than along the western one.

During the period of surveys it was observed that anchovy stock was decreasing.

DISCUSSION

The main causes of errors in stock assessments which use egg and/or larva surveys can arise from several factors. The most important errors caused by use of inappropriate gear, non-random distribution of eggs in plankton, bad estimate of temperature-developmental time relationships in eggs and larvae, bad estimates of mortality rates, errors in estimates of total egg production during the spawning season, and by wrong estimates of relative fecundity. The main errors are the consequence of relative fecundity estimates and of estimates of total number of eggs produced during the spawning season using the interpolation of number of eggs produced during the time of survey over the curves of spawning intesity. The analysis of data obtained on anchovy stock assessment in the Adriatic show that the gear was chosen. Namely, two sets of comparison of different plankton nets (Dicenta et al., 1976; Regner, 1981) showed that Bong-20 net is one of the most suitable gear for quantitative sampling of anchovy eggs. It seems also that temperature-developmental time relationships were analyzed accurately, because, it was confirmed many times during the field investigations that it was possible to foresee exactly which stages would be found in plankton if surface temperature of the sea water was known. Consequently, it can be expected that instanteneous mortality rates were also fairly well estimated, if possible errors moving to probable changes of spawning intesity durivg D days of spawning, and to immigration or emigration of eggs into the surveyed sub areas due to drift of currents, are neglected. It seems also that the errors caused by non-random distribution of eggs, temperature-developmental time relationships, and of mortality rates can be relatively accurately estimated using formerly described statistical procedures.

The errors coming from the variability of the curves of spawning intesity cannot be estimated for two main reasons. The first one is that they are, as it was mentioned before, polymodal, while the second one is the fact that they do not reflect real changes of spawning intesity over entire spawning season, since the centres of spawning are changing place during the spawning season (Štirn, 1969; Regner et al., 1985). But if the method of batch fecundity is used, there is no longer any need for the use of spawning intesity curves, and so this error can be easily avoided.

As it was mentioned before, relative fecundity of anchovy in the Adriatic was estimated by summing three or four lots of oocytes found in their ovaries. Today it is quite clear that these estimates were wrong, since it is known from the case of northern anchovy (Hunter and Goldberg, 1980) that females can spawn every 6–8 days, and that the number of spawnings can be more than 20 during the spawning season. As the same features were later found in a number of serial spawners, particularly in many species of clupeoid fishes, it is obvious that relative fecundity of Adriatic anchovy was underestimated and that, consequently, their stock was overestimated.

If the mean value of relative fecundity of Adriatic anchovy (Varangolo, 1967; Piccinetti et al., 1979) is divided by 3, it can be estimated that the mean relative batch fecundity is 417.5 eggs per gram of female. As far as the sex ratio in anchovy is concerned, it was reported from many papers that it was 0.5. For the spawning fraction of anchovy the mean value of S for the northern anchovy, *Engraulis mordax,* was calculated from the data given for the period from 1980 to 1984 by Picquelle and Stauffer (1985), which was found to be 0.1244. These values were substituted in the equation:

$$\bar{B} = \frac{\bar{E}}{F_{rb}\, S\, R} \tag{3}$$

so we got:

$$\bar{B} = \frac{\bar{E}}{417.5 * k * 0.1244 * 0.5}$$

where k is the conversion factor from grams to metric tons ($1*10^6$). The following results were obtained:

Year	Anchovy	
	estimated biomass (tons)	corrected biomass
1976	1 095 919	408 976
1977	5 676 674	314 897
1978	4 076 982	1 028 986
1979	1 858 352	461 350
1980	2 494 226	589 588
1981	1 264 203	327 027
1982	1 939 954	556 085
1983	1 366 743	330 108
1984	1 391 224	359 029
1989	139 134	24 795
1990	232 418	41 503

Mean biomass of anchovy estimated from relative fecundity data and estimates of total number of eggs produced using integrations over the curves of spawning intesity was 1 955 075 tons, while the mean biomasss estimated from stimulated batch fecundity method gives the value of 403 850 tons. Although estimates using the batch fecundity method are rough simulations, they show that anchovy stocks were highly overestimated because their fecundity was underestimated. It is obvious that in future surveys, the batch fecundity methods has to be applied.

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OCENA STADA SARDELI (*ENGRAULIS ENCRASICOLUS* L.) W ADRIATYKU NA PODSTAWIE ILOŚCI IKRY W PLANKTONIE

STRESZCZENIE

W niniejszej pracy przedstawiono dotychczasową ocenę stada sardeli w w Adriatyku na podstawie ilości ikry w planktonie w czasie prowadzenia badań na morzu w okresie 1976–1984 oraz 1989–1990.

W pracy przedstawiono również i dyskusję o wpływie krzywych intensywności tarła na błąd w ocenie stada sardeli. Na podstawie badań stwierdzono, że stado sardeli zmniejsza się z roku na rok. Zastosowanie metody "batch fecundity" przy ocenie stada pozwala na stwierdzenie, że stado sardeli było znacznie przecenione ponieważ płodność była nie doceniana. Potwierdza to, że w przyszłych badaniach do oceny stada sardeli powinno się stosować metodę "batch fecundity".

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