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ESTIMATION OF GROWTH, MORTALITY, PRODUCTION AND STOCK SIZE OF SARDINE, *SARDINA PILCHARDUS* (WALB.), FROM THE MIDDLE ADRIATIC

ODREĐIVANJE RASTA, SMRTNOSTI, PRODUKTIVNOSTI I VELIČINE POPULACIJE SRDELE, *SARDINA PILCHARDUS* (WALB.), SREDNJEG JADRANA

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Age, growth, mortality, production and stock size were studied on the material of *Sardina pilchardus* from the middle Adriatic. Samples were collected between September 1979 and March 1981. Age was determined by means of alizarine stained otoliths. Calculated von Bertalanffy's growth constants were. $L_{\infty} = 20.5$ cm; $K = 0.46$; $t_0 = -0.5$. Instantaneous mortality rates, survival rate and exploitation rate were estimated as a function of age. The stock size of the eastern middle Adriatic sardine population for the period 1979—1981 and annual sardine production were estimated.

INTRODUCTION

The knowledge of the basic biological parameters such as growth and mortality is essential for the studies of the dynamics of any fish population, particularly in relation to its behaviour under exploitation and it is of practical significance for fishery regulation. With regard to commercial importance of sardine population in Yugoslav commercial fishery, particular attention has been given to the studies of biological parameters of the species for an proper utilization and management purposes.

MATERIALS AND METHODS

The material used for age, growth and morality studies was obtained from commercial (purse seining) pelagic catches. They were realized from the coastal waters of the middle Adriatic, from September 1979 to March 1981.

A total of 955 sardine specimens were examined. Data on sardine total length are expressed in centimetres and body weight in grams.

Otoliths were used for ageing the sardine which may often be a pretty difficult estimation due to frequently relatively mild winter periods and migrations. Therefore, many different techniques had been applied before an optimum method for sardine age determination was obtained (Sinovčić, in the paper by Levi, D. and J. Mortera, 1981).

Von Bertalanffy's growth equation as modified by Beverton and Holt (1957) which relates length l to age t was fitted for the growth calculation.

Instantaneous rate of total mortality (Z) was estimated by Beverton and Holt's equation (ibid.), instantaneous rate of natural mortality (M) after Taylor's method (1959), survival rate (S) after Gulland (1964) and instantaneous rate of fishing mortality (E) and rate of exploitatin (E) after Beverton (1963). Annual production was calculated by Allen's method (1971) and sardine population size (N) after Baranov's catch equation (quoted by Ricker, 1975).

RESULTS AND DISCUSSION

Growth

The sardine specimens ranged from 8.9 to 20.3 cm in total length, and from 4.4 to 72.38 g in weight. During the period of observations the total sardine commercial catch in the middle Adriatic varied from 6,302 to 15,112 tons.

Growth parameters were obtained graphically (Gulland and Holt, 1959), where mean lengths of a defined age group was plotted against mean length of successive years (Ford-Walford approach). The slope of the line gave an estimate of the growth coefficient (K = 0.46). The maximum theoretical length (L_{∞}) that examined individuals showed for the studied period was 20.5 cm. Value t_o, i. e. hypothetical age that corresponds to value l_o according to von Bertalanffy's growth equation was calculated by the following relation:

$$t_o = t + (1/K)\ [ln\ (L_{\infty} - L_t)/L_{\infty}]$$

Where

L_t = length at t years of age

t = age in years

Calculated growth constants for sardine population from the middle Adriatic are: $K = 0.46$, $L_{\infty} = 20.5$ and $t_0 = -0.5$. According to our results, von Bertalanffy's exponential growth equation for sardine population from the middle Adriatic has this form:

$$l_t = 20.5\ [1-e^{-0.46\ (t\ +\ 0.5)}]$$

The estimate of $L_{\infty} = 20.5$ cm corresponds closely to the maximum observed length (20.3 cm). Also the value of $t_0 = -0.5$ corresponds closely to the hatching period of sardine eggs which indicates that this parameter has been correctly estimated.

Growth coefficient ($K = 0.46$) is very similar to that which was obtained by Beverton (1963) on the basis of the data from 1946 to 1952 (Mužinić, 1954) for the sardine from the eastern Adriatic ($K = 0.45$). In addition, similar values were recorded for sardine from the western Mediterranean. Larañeta (1965) obtained the values of $L_{\infty} = 20.3$ cm and $K = 0.31$, and Andreu *et al.* (1950) the values of $L_{\infty} = 20.5$ cm and $K \cong 0.5$.

It's a general tendency that species which show high L_{∞} have low K. The inverse relationship between growth rate and asymptotic fish length were differently explained by different authors. Gunter (1950) associated this relationship with environmental temperature and held that higher temperature forced an earlier sexual maturation, growth was accelerated what resluted in smaller final length. Taylor (1959) found that the change of annual mean temperature from 4 to 5°C affected the decrease of L_{∞} for 29 cm in the species *Gadus callarias*. The same author also suggested that fishery biologists often overestimated the impact of man and underestimated the natural influence. Beverton and Holt (1957) belived that the growth was primarily dependent on the population density and that food quantity was the limiting factor. They held that the change of growth intensity was due to fishing which affected the reduction of stock, the available food quantity getting thus increased what finally resulted in the accelerated growth. Anyhow, temperature affects the growth since the growth is stopped in winter. This growth break in winter may be due to the physiological process of food intake or to the fact that temperature affects the reduction of the quantity of organisms on which sardine feed.

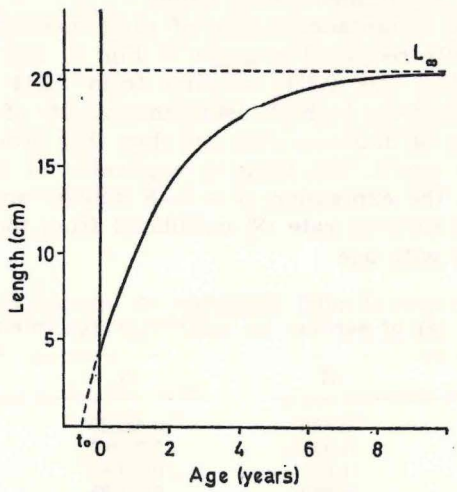

Fig. 1. Growth curve of sardine from the middle Adriatic for 1979—1981

Exponential curve of growth in length of the Adriatic sardine is given in Fig. 1. It shows greater length increment in the first and second year of age upon which time the growth in length flattens out and stabilizes at the sixth year of age.

The analysis of sardine commercial catches from the middle Adriatic showed the following percentage proportion of individual age — groups:

Age group	1+	2+	3+	4+	5+	6+	7+	8+
Percentage	9.95	11.44	30.35	18.41	13.93	8.96	4.48	2.49

Sardine at age 1 to 8 were recorded from analyzed samples. Specimens of three and four age groups made up the highest proportion (48.76%).

The comparison of maximum length of sardine from our samples with the asymptotic length gave the value of 0.99 which in fact means that 99.0% of potential sardine lenght was attained within the age reached by observed specimens.

Mortality

Instantaneous rate of total mortality (Z) was determined after Beverton and Holt's equation (1957):

$$Z = K\,(L_{\infty} - \bar{l})/(\bar{l} - l')$$

where $\bar{l}$ is the mean length and l' the smallest length of fish that was recorded from all catch samples.

Biases in mortality estimate were avoided to a certain extent by taking into consideration only the specimens of third to eight year of age thus eliminating effects of recruitment on its value.

Variations of the instantaneous rate of total mortality of sardine specimens which were fully recruited is given in Fig. 2. The mean instantaneous rate of total mortality was 0.736, ranging from 0.244 to 1.060 (Table 1). Sardine of age 4 showed the highest instantaneous rate of total mortality with an apparent tendency of decrease with age thus that lowest value was recorded in specimens of age 7. The same is applicable to the annual mortality rate calculated from the expression $A = 1 - S$ which varied from 21 to 65%.

On the contrary, survival rate (S) calculated from the expression $S = e^{-Z}$ showed an increment with age.

Table 1. Instantaneous rate of total mortality (Z), annual mortality rate (A) and survival rate (S) of sardine for individual age intervals

Interval	Z	S	A
2+ to 3+	0.886	0.41230	0.58770
3+ to 4+	1.022	0.35987	0.64013
4+ to 5+	1.060	0.34646	0.65354
5+ to 6+	0.882	0.41395	0.58605
6+ to 7+	0.521	0.59393	0.40607
7+ to 8+	0.244	0.78349	0.21651

Mean value of the instantaneous rate of total mortality (Z) shows that during the observation period 48% of sardine population from the study area survived.

Instantaneous rate of natural mortality ($M = 0.5$) was calculated by Taylor's equation (1959). However, instantaneous rate of natural mortality could be calculated for some species by growth parameters. Species which approach their asymptotic length, faster that is which show high value of K are likely to have high M and low L_∞ and »vice versa«. Our results on sardine showed intermediate values.

Proportion between instantaneous rate of natural mortality and growth coefficient is different in different species.

Beverton and Holt (ibid.) gave a comparative review of growth and mortality referring to fishing for several clupeoid and engraulid species. They held that essential biological characteristics which determined the response of the commercial part of the stock to the intensity of exploitation are contained in the magnitude in two ratios, that of the instantaneous rate of natural mortality (M) to the growth parameter (K) — M/K, and that of the length at first maturity (L_m) to the asymptotic length (L_∞) — L_m/L_∞. The same authors found that the values of ratio between M and K were between 1 and 2 in almost all the studied species. They found $M = 1.2\,K$ for clupeids which is very similar to that we found ($M = 1.1\ K$).

In addition, the values of ratio between L_m and L_∞ are between 0.7 and 0.8 for almost all the species. For sardine from the middle Adriatic this value was 0.7 (Sinovčić, 1983).

By means of these values the same authors constructed curves of equilibrium catch per recruit as a function of rate of exploitation (E) for various species. All the curves were similar and none reached the maximum at a level of fishing intensity which was likely to be attained in practice.

Accordingly, these authors concluded that many species which, at the first sight had different dynamical properties similarly responded to fishing.

The value of instantaneous rate of fishing mortality $F = 0.236$ was obtained from the expression $Z = F + M$.

Exploitation ratio $E = 0.321$ was calculated from the quotient of the instantaneous rate of fishing mortality (F) to the instantaneous rate of total mortality (Z).

The following are the mean values of all the parameters:

$Z = 0.736$
$M = 0.5$
$F = 0.235$
$S = 48\%$
$A = 52\%$
$E = 0.321$

Production

Annual production P of sardine population was calculated by Allen's method (1971).

$$P = 3\,N_o\,KW_\infty\,(1/M + K - 2/M + 2K + 1/M + 3K)$$

where N_o is the initial number, M is the instantaneous rate of natural mortality and K and W_∞ parameters of the growth equation, and it was estimated to be 19.03 N_o g.

Population estimation

Sardine population from the eastern middle Adriatic was estimated by Baranov's (1918) catch equation.

$$N = CZ/FA$$

where C is the catch, Z, A and F the instantaneous rate of total, annual and fishing mortality.

From all these parameters the biomass of sardine from the middle Adriatic was estimated to be 91,018 tons for the period of observations.

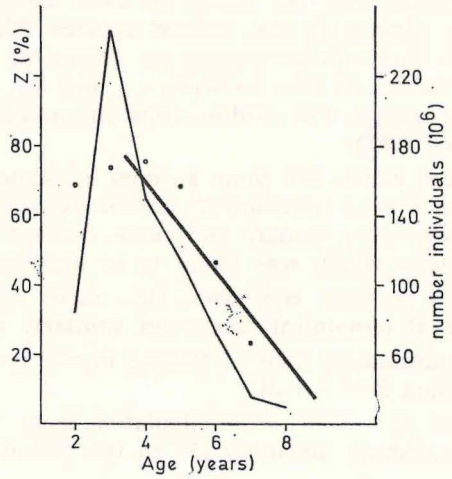

Fig. 2. Catch curve (———) and total mortality curve (———) for sardine from the middle Adriatic for 1979—1981

CONCLUSIONS

The results of this study showed the following:

— Calculated von Bertalanffy's growth constants were: $L_\infty = 20.5$ cm, $K = 0.46$ and $t_0 = -0.5$. The growth curve fitted with these values shows greater length increment in the first and second year of age and stabilizes at sixth year.

— Sardine specimens sampled from commercial catches belonged to 1+ to 8 + age groups. Individuals of 3 + age group were most frequently present (35.05%).

— Mean value of instantaneous rate of total mortality was estimated to be $Z = 0.736$. The mean annual mortality represent 52% of the total population. Sardine of age 4 showed the highest annual mortality of 65%. The instantaneous rate of natural mortality $M = 0.5$ was calculated from the relation $Z = M + F$ as well as the fishing mortality rate $F = 0.236$.

— Exploitation ratio $E = 0.321$ and survival rate of 48% were calculated.

— The stock size of sardine from the eastern area of the middle Adriatic for the period 1979—1981 was estimated to be 91,018 tons, with annual sardine production of 19.03 N_0g. These results showed that the sardine population was not sufficiently exploited during the investigated period.

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ODREĐIVANJE RASTA, SMRTNOSTI, PRODUKTIVNOSTI I VELIČINE POPULACIJE SRDELE, *SARDINA PILCHARDUS* (WALB.), SREDNJEG JADRANA

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KRATKI SADRŽAJ

Starost, rast, smrtnost, produktivnost i veličina stocka srdele (*Sardina pilchardus* Walb.) u području srednjeg-istočnog Jadrana izučavana je u vremenskom razdoblju od rujna 1979. do ožujka 1981. godine.

Starost u riba utvrđena je pomoću otolita na način da su otoliti bojani u alizarinu.

Analizirani primjerci srdele iz komercijalnih lovina u području srednjeg-istočnog Jadrana, bili su stari (godišnje klase): od 1 + do 8 + u kojem je uzorku godišnja klasa 3+ brojčano bila najzastupljenija.

Izračunate vrijednosti konstanti von Bertalanffyjeve jednadžbe rasta su: $L_{\infty} = 20{,}5$ cm, $K = 0{,}46$ i $t_0 = -0{,}5$.

Koeficijenti smrtnosti, omjer preživljavanja kao i omjer iskorištavanja populacije računati su pomoću funkcije smrtnosti između godišnjih klasa u analiziranom uzorku.

Izračunata veličina stocka srdele u srednjem istočnom Jadranu, za razdoblje 1979—1981. godine iznosi 9.018 tona. Utvrđena vrijednost količine srdele u području srednjeg istočnog Jadrana za razdoblje 1979—1981. u odnosu na ukupan godišnji ulov ukazuje da bi se razina iskorištavanja stocka u ovom dijelu Jadrana mogla znatnije povećati.