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Some ecological aspects of juvenile anchovy, *Engraulis encrasicolus* (L.), under the estuarine conditions (Novigrad sea - Central Eastern Adriatic)

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Some ecological aspects of 2574 juvenile anchovy, Engraulis encrasicolus *specimens were studied using monthly purse-seine samples of catches from August 1989 to March 1991, from the Novigrad Sea and the Karin Sea (central part of the Adriatic). Anchovy attained first sexual maturity at the end of their first year of life. Fifty per cent maturity was reached at 9.0 cm of total length (logistic model). At 11.5 cm the whole anchovy population is sexually mature. The length-weight relationship for all fish was described by the following parameters:* a = *0.0038;* b = *3.1939* (r^2 = *0.99); positive allometry was established. The mean length - at age values varied between 4.2 cm (age of four months) to 10.6 cm (age of one year). The von BERTALANFFY growth parameters of juvenile anchovy were estimated as* $L\infty$ = *13.2 cm total length,* K = *0.82 per year and* t_0 = *-0.5.*

Key words: Juvenile anchovy, *Engraulis encrasicolus*, Novigrad Sea, eastern Adriatic, estuarine conditions

INTRODUCTION

Survival during the first year of life determines the year-class strength of many fish. The degree to which biotic or physical factors regulate recruitment of fish from larval to juvenile stages varies from one system to another and even temporally within systems.

The crucial point in understanding the fluctuations of year class strength in fish species is seen in the recruitment phase. Food availability (LASKER,1981), abiotic conditions (ALHEIT, 1989) and/or predation (HUNTER, 1981) are significant factors for controlling survival, growth and abundance of the early stages. The estimation *vice versa* of these parameters is necessary to assess the actual recruitment situation and, in the longer term, make forecasts possible for the different year classes. The factors promoting or inhibiting recruitment are the subject of intense interest both in theoretical analysis and practical management of fish populations.

Since the 1983-1985 period anchovy landings in the Adriatic Sea have decreased greatly (SINOVČIĆ *et al.*, 1991; SINOVČIĆ, 1992, CINGOLANI *et al.*, 1996). It can be related to decrease of the anchovy population itself or reduced fishermen stimulation for anchovy catch. Many attempts have been made to explain pelagic fish population size fluctuations in the variety of ways (REGNER *et al.*, 1981; SINOVČIĆ *et al.*, 1991; SINOVČIĆ, 1992; SINOVČIĆ and ALEGRIA, 1997). We noticed strong anchovy year class in 1989 and 1990.

This paper deals with some ecological aspects of juvenile anchovy. The relationship between anchovy strong year-class appearance in 1989 and 1990 in the estuarine habitat and the anchovy catches having entered into exploitation phase, is examined as well.

MATERIAL AND METHODS

Representative anchovy samples were collected monthly between August 1989 and March 1991. Anchovy were caught by purse seines under artificial light, during darks of the moon. A total of 2 574 juvenile anchovy specimens ranging from 4.4 to 12.5 cm and from 0.4 to 13.8 g were obtained by random sampling from the interconnected bays of the Novigrad Sea and the Karin Sea, which are under strong influence of the Zrmanja River (Fig. 1).

After measuring the total length of each fish to the nearest 0.1 cm, the body weight was measured and given in decigrams. Data on the fish length were placed in halfcentimetre groups. Lower class limits were used.

In order to establish the juvenile space and time anchovy distribution , the network of location points was created which refers to the geographical position of realised purse seine (mesh size of 9 mm) juvenile anchovy catches.

Otoliths (sagittae) were taken for age determination. Gonads were removed and weighed. The empiric scale applied by SINOVČIĆ (1978,1992) was used for macroscopic estimation of anchovy gonad state in the maturation analysis.

For the estimation of minimal length at 50%, 95% and 100% maturity of the population, logistic model was applied :

$$P(x_i) = \frac{a}{1+e^{b+cx}}$$

where Pxi is the proportion of most advanced maturity stages of gonads (maturity stages V and VI, SINOVČIĆ, 1992) of anchovy individuals in each size interval, x the mean length of the length class ; a, b and c are constants.

The method of GULLAND (1969) was used to calculate the von BERTALANFFY (1938) growth equation parameters $L\infty$ and K. The parameter t_0 was calculated according to PAULY (1980).

The length-weight relationship was determined according to the equation:

$$\log W = \log a + b \log TL$$

where W = fish weight in g; TL = total length in cm; a and b = constants.

Mean length and weight data of 0.5 cm length classes were used in analysis.

STUDY AREA

The Novigrad Sea and the Karin Sea are rather isolated bays, deeply cut in the mainland. The Zrmanja River mouth is in the central, north coast of the area (Fig.1).

Due to the considerable inflow of fresh water from the Zrmanja River, as well as many streamlets and numerous springs, this area has characteristics of an estuary.

The Novigrad Sea covers the area of 30 square km with 28 m depth in the central part area and the water mass of 0.5 cubic km. It is bigger than the Karin Sea, which covers the surface of 5.4 square km and with the volume of 0.04 cubic km. The isobath of 10 m is very close to the coast. Both of them are interconnected with the strait 150-250 m wide, 2.5 km long and 12 m deep. On the other side, the Novigrad Sea is connected with the neighbouring Velebit Channel, the canyon of steep shores going down 40m below the sea level.

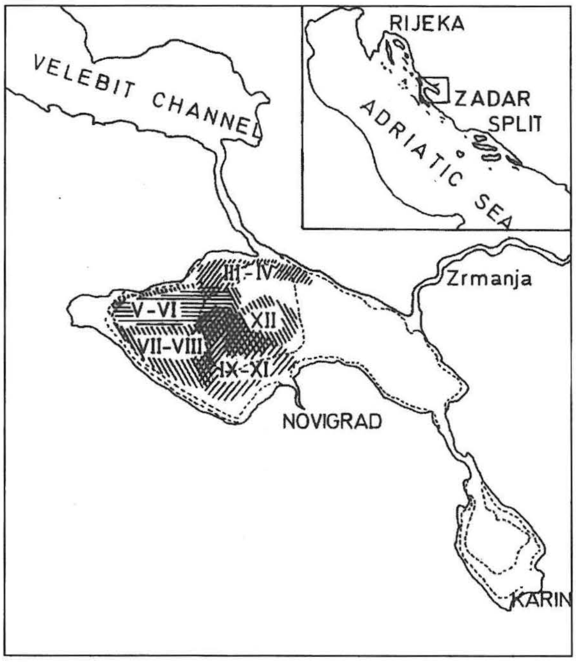

Fig. 1. Map showing the investigation area as well as the space and time distribution of juvenile anchovy in the Novigrad Sea during 1990

ENVIRONMENTAL PARAMETERS

Abiotic factors

Hidrography

The most important parameters which define physical-chemical qualities of the Novigrad sea and affect the distribution and abundancy of anchovy population are: temperature, salinity and food content.

Data displayed on Figure 2 represent the average monthly temperature variations (1 m depth) in the bay of the Novigrad Sea during 1990. During the research period, the lowest surface temperature of 4.1°C was noted in the neighbouring Karin Sea in January which is, according to ZORE-ARMANDA (1969), the lowest temperature registered in the Adriatic Sea. Namely, the influence of the Zrmanja River fresh water has much more influence on the Karin Sea because of the Zrmanja bed. The main current of the Zrmanja flows off towards the Karin Sea . The highest surface temperature of 23.2°C was noted in the Karin Sea. In 1990, the highest average annual temperature amplitude was $\Delta t = 15.2°C$, e.g. between the lowest average monthly temperature of 7.8°C noted in March and highest of 22.0°C noted in August 1990.

During autumn and winter, the existence of warmer sea water is noted in the deeper layers of the Novigrad Sea (KRŠINIĆ, 1987). These are the residuals of the summer water, which entered the area from the Velebit Channel by deep sea compensation current.

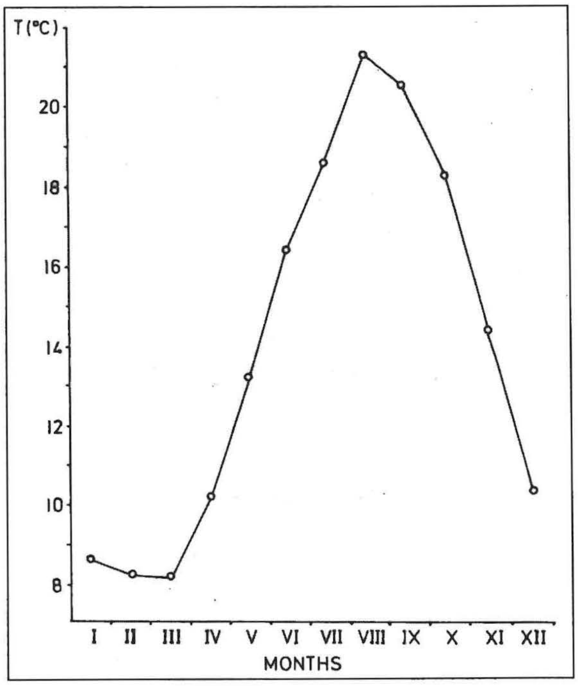

Fig. 2. Monthly temperature changes in the Novigrad Sea area during 1990 (1m depth)

Nutrients

The concentration of nutrients due to freshwater inflow results in a high primary productivity. This is the base of a food web where fytoplankton provides abundant and diversified prophic resources to fish post-larvae, juveniles as well as to adults.

The values of phosphate amount to 0.25 $\mu mol\ l^{-1}$ and especially silicates, which reach up to peak values of 12.8 $\mu mol\ l^{-1}$ in the Novigrad Sea and 30.8 $\mu mol\ l^{-1}$ in the Karin Sea (Table 1) make this area one of the richest in the eastern part of the Adriatic, which, generally speaking, is oligotrophic due to the quantity of the nutrients.

Table 1. Physical-chemical characteristics and nutrient concentrations in the Karin Sea and the Novigrad Sea (BULJAN, 1969), as well as in the Velebit Channel and the Nin Bay (ŠKRIVANIĆ and BARIĆ, 1979)

Area	Salinity psu	Temp. °C, min-max	PO_4-P µmol l^{-1}, min-max	NO_3-N µmol l^{-1} min-max	SiO_2-Si µmol l^{-1} min-max
Karin Sea	19.52-36.60	4.1-23.4	0.00-0.25	-	3.89-30.80
Novigrad Sea	11.72-36.92	4.6-23.0	0.00-0.25	-	10.00-12.80
Velebit Channel	34.10-37.92	8.0-23.1	0.02-0.05	0.02-0.60	0.60-4.00
Nin Bay	36.50-38.10	7.9-24.7	0.02-0.06	0.14-0.40	1.00-4.00

The characteristic of this area is rather high level of oxygen saturation, almost 100%, particularly during spring and summer. In June the values were as high as 128% (BULJAN,1969). These values point to the possibility of a rapid biological processes, that is consumption of nutrients as well as the processes of oxydation of organic matter coming from the mainland. Owing to these facts the area is well aired with the high level of self purification.

Biotic factors

Phytoplankton and zooplankton

Phytoplankton quantity is important to determine the trophic level of marine ecosystems. The development of phytoplankton populations is dependent upon the concentration of nutrients and other ecological factors such as light, temperature, salinity, quantity and composition of organic matter, currents and grazing. Maximum phytoplankton value occurs in the area where the environmental conditions become optimal or nearly optimal for the increasing of the existing populations.

Completing the categorization of some eastern parts of the Adriatic ecosystems on the basis of the phytoplankton cell volume, VILIČIĆ (1989) noted the highest values in the Novigrad Sea and the Karin Sea Bays as well as in the urban area of Šibenik. Based on the phytoplankton quantity, the Novigrad Sea and the Karin Sea are in the highest category of naturally eutrophicated areas. In that respect only the Gruž (Dubrovnik) and the Šibenik harbours are richer (VILIČIĆ, *ibid.*). However, high production in these areas is the result of urban eutrophication, while the Novigrad Sea and the Karin Sea Bays are naturally eutroficated.

South and west afforested coasts are the richest and most productive parts of the area. Together with the rain, there comes also the organic matter, enriching the area with the nutrients fulfilling the basic precondition of phytoplankton, as well as zooplankton swelling. Results of the tintinnines quantity research, particularly of the species: *Helicostomella subulata, Tintinnopsis campanula, Tintinnopsis compressa and Stenosemella ventricosa,* which are the components of the juvenile anchovy food (ERCEGOVIĆ, 1940; SINOVČIĆ, 1992), showed increased amounts in the Novigrad Sea, particularly during spring and summer if compared to some other parts of the eastern Adriatic. The amounts show that these groups of organisms make this area the richest one on the eastern part of the Adriatic Sea which is very important ; plankton organisms present basic food for pelagic species.

RESULTS AND DISCUSSION

Spacial and temporal distribution of the juvenile anchovy population

Due to their position in the trophic chain, small pelagic fish react very quickly to the increase of phytoplankton and zooplankton production, influencing trophic relations in the sense of carrying organic matter from lower to higher trophic levels.

The Novigrad Sea plays a nursery and feeding role for juvenile anchovy. Juveniles remain there as they increase in size before migrating into deeper, open waters of the Adriatic sea. Data on catches from different parts of the Novigrad Bay in different seasons indicate that juvenile anchovy schools keep close to the Novigrad Sea entrance (Fig. 1). During summer they spread their presence to the south and the west, afforested and more productive coast of the bay. In autumn they migrate to the deeper waters, but in winter they move to the deepest, central part of the bay, where the temperature conditions are the most favourable. Namely, in the deepest, central part of the bay, the compensative water originated from the Velebit Channel is situated there as a residue of the summer water which entered the area by deep sea compensation current (KRŠINIĆ, 1987).

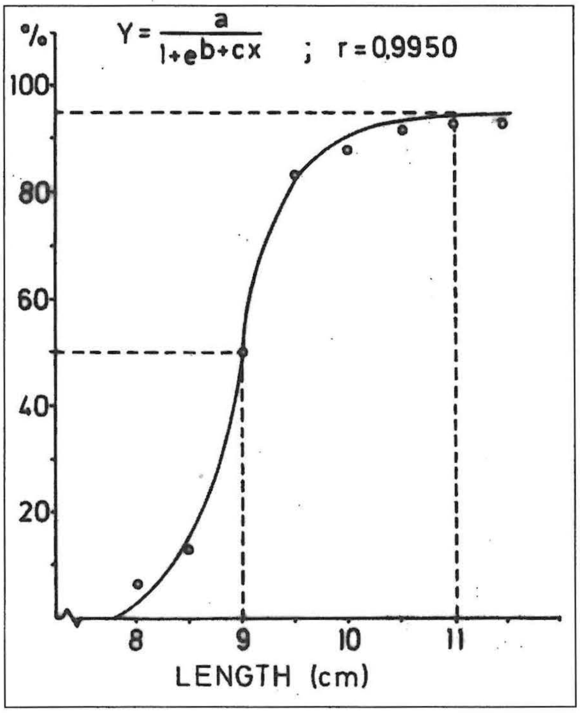

Fig. 3. Percentages of most advanced maturity stages of male and female anchovy specimens (V and VI stages of sexual maturity) as a function of total length, Novigrad Sea, 1990

First sexual maturity of male and female anchovy

Data displayed in Fig. 3 present the lowest size of sexual maturation from the presence of the most advanced stages of gonads (V and VI stages, SINOVČIĆ, 1992) of both sexes with the lowest lengths on the basis of the logistic model. Data depict that the smallest specimens with the signs of sexual activity were male from the length class of 8.0 cm.

Fifty per cent of the anchovy population reaches maturity at the minimum total length of 9.0 cm, while 95% of anchovy population becomes mature at the 11.0 cm of the minimum total length. At the 11.5 cm the whole anchovy population is sexually mature. Highly significant correlation is found (r = 0. 99).

Age and growth of juvenile anchovy

The total length of fish used for obtaining growth estimation ranged from 4.4 to 12.5 cm and weight from 0.4 to 13.8 g (Table 2). They represented 0+ (98%) and 1+ (2%) age groups.

The actual growth curve of juvenile anchovy are represented in Fig. 4. The growth pattern was divideed into two periods : rapid growth by age of ten months and slower one after that period to the end of the anchovy first year of life. The mean lengths at the age (in

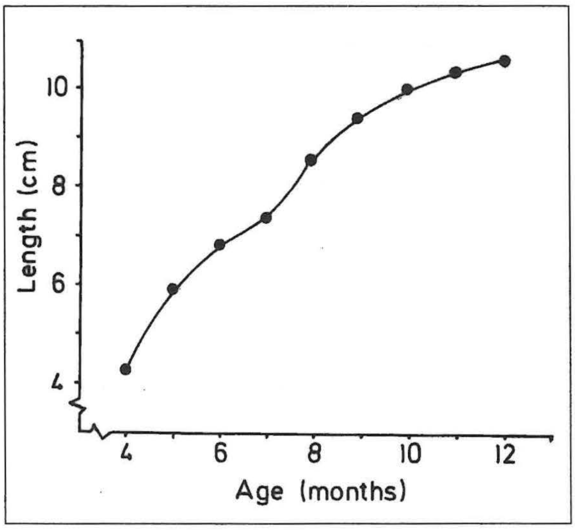

Fig. 4. Growth pattern and average lengths - at age (in months) of juvenile anchovy in the Novigrad Sea

months) of juvenile anchovy varied between 4.2 cm (age of four months) to 10.6 cm (age of twelve months).

The resulting von BERTALANFFY growth parameters of the juvenile anchovy are : $L\infty = 13.2$, $K = 0.82$, $t_0 = -0.5$.

Using the method of PAULY (1980) the parameter of t_0 was estimated as -0.5.

The growth equation of juvenile anchovy is:

$$l_t = 13.2\ [1\text{-}e^{-0.82(t + 0.5)}]$$

Growth of the juvenile anchovy is followed with respect to modal lengths which varied between 6.0 cm (August 1989) and 9.5 cm (March 1990) i.e. from 8.0 (July 1990) to 10.0 cm (March 1991); and mean lengths, which varied between 6.7 cm (July1989) and 10.3 cm (March 1990). i.e. between 7.3 cm (July 1990) and 10 cm (March 1991).

Figure 5 shows comparison of the achieved anchovy average total lengths in the same months in the different year classes. The weight increase was noted in the 1990 year class of anchovy, probably due to the lower anchovy population density. Namely, anchovy population was reduced to the optimal extent, and the remaining population had more available food at their disposal. The result of favourable feeding of juvenile anchovy is a faster growth.

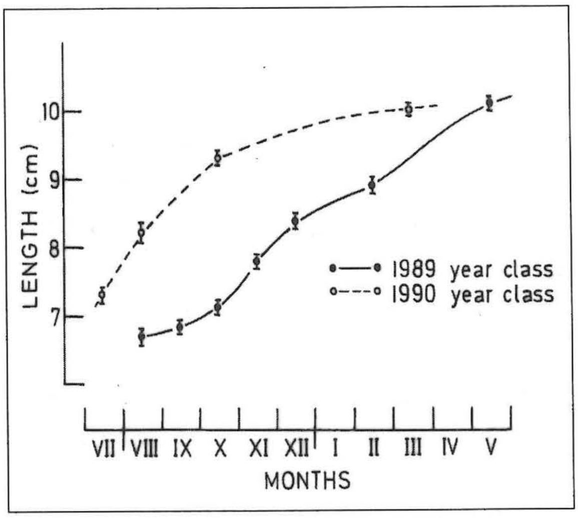

Fig. 5. Variations of average anchovy total length as a function of sampling month and year class in the Novigrad Sea

Lenght-weight relationship of juvenile anchovy

The length-weight relationship of the juvenile anchovy is obtained from the length and weight of specimens ranging from 4.4 to 12.5 cm and from 0.4 to 13.8 g for different sampling periods. The values are given in Table 2 and Fig. 6. Allometric growth was observed in the growth characteristics of the whole juvenile anchovy in the Novigrad Sea (b = 3. 1939; $r^2 = 0.998$). In October 1989 and 1990 juvenile anchovy specimens showed more or less "ideal" body form. In December 1989 they displayed negative allometric form while in August 1989 they displayed mostly positive allometric form. Their body form in other months was morphologically positioned between the form of August and December 1989.

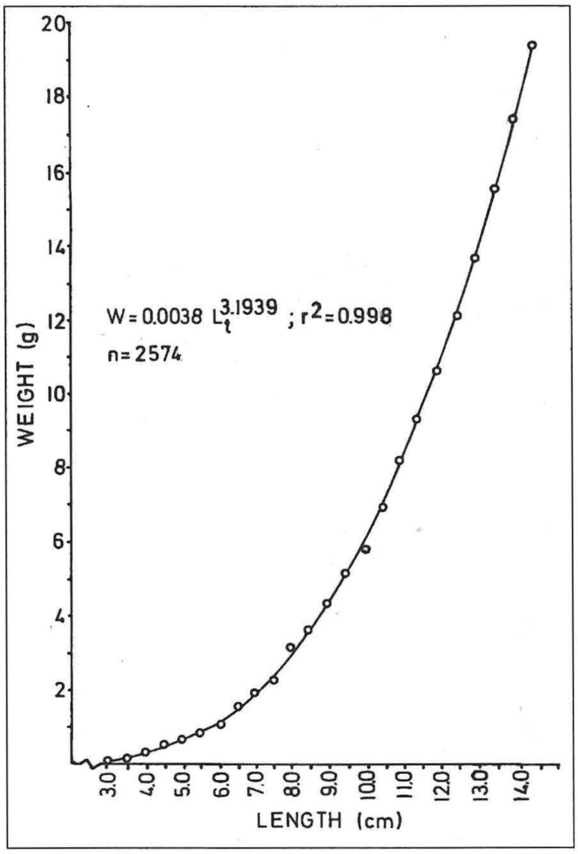

Fig. 6. Length-weight relationship of the juvenile anchovy sampled in the Novigrad Sea in the period between August 1989 and March 1991

Table 2. Juvenile anchovy, Engraulis encrasicolus. *The monthly relationship between* W *(dependent variable) and* L *(independent variable), data for the 1989 and 1990 year classes. Regression of type log* W = *log* a + b *log* L *where* W *is weight (g) and* L *is length (cm);* a *is the regression constant and* b *is the regression coefficient,* n *= number of fish,* X *= mean length,* s *standard deviation,* s_x *= standard error of a mean and* r^2*= coefficient of determination*

Date	x	s	s_x	Length range (cm)	Weight range (g)	b	$a(x10)^3$	r^2	n
23.08.1989.	6.7	0.7295	0.1200	5.3-8.7	0.5-3.6	3.4200	2.1	0.998	125
12.09.1989.	6..8	0.7800	0.0462	5.0-9.0	0.5-3.6	3.1308	3.7	0.998	285
3.10.1989.	6.8	0.7200	0.0410	5.3-9.0	0.7-3.7	3.0293	4.7	0.998	309
17.10.1989.	7.4	1.0026	0.0900	5.0-9.5	-	-	-	-	124
12.12.1989.	8.4	0.9623	0.0773	6.1-12.4	1.3-10.8	2.9500	6.0	0.993	155
15.02.1990.	8.9	1.2394	0.0787	5.6-11.8	0.8-13.8	3.1979	3.3	0.997	248
22.03.1990.	10.3	0.4460	0.0543	8.0-12.5	2.5-13.8	3.2395	3.1	0.998	249
10.05.1990.	10.2	0.8081	0.0987	8.0-12.3	2.5-10.9	3.1677	3.9	0.996	83
30.07.1990.	7.3	1.2200	0.0750	4.4-10.2	0.4-6.1	3.2029	3.7	0.997	266
30.08.1990.	8.2	1.1700	0.0872	5.3-12.1	0.7-10.3	3.2040	3.6	0.998	180
2.10.1990.	9.3	0.8261	0.0584	6.1-11.8	1.6-11.2	3.0900	5.0	0.999	200
14.03.1991.	10.0	0.7367	0.0533	7.5-12.0	2.1-8.2	3.0072	5.0	0.991	191
17.04.1991.	10.1	0.8053	0.0660	8.4-11.9	3.5-10.5	3.1497	4.2	0.999	149

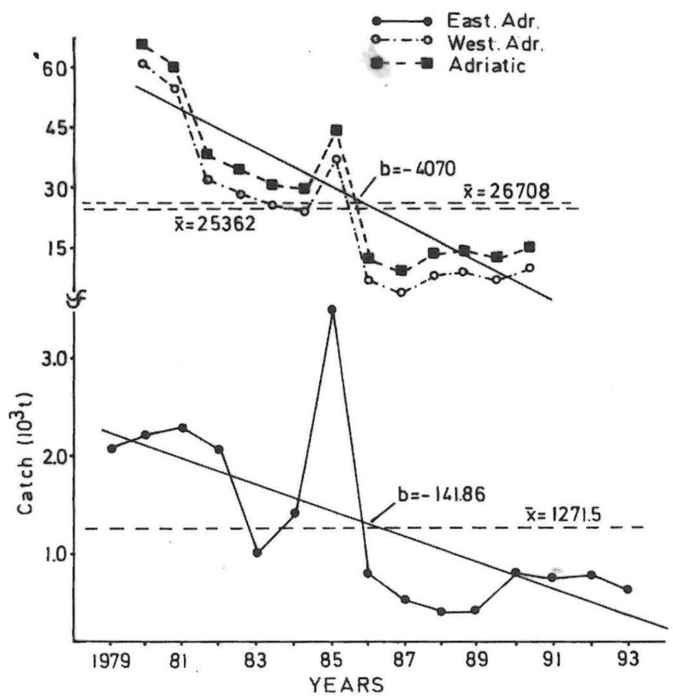

Fig. 7. Fluctuations of anchovy annual catches in the Adriatic Sea during the 1979-1993 period

Catches

The influence of strong year class observed in 1989 and 1990 during usual monitoring on the overall catches of this species in the eastern part of the Adriatic is shown in Fig. 7. The catches obtained in the western part of the Adriatic and catches in overall Adriatic Sea are shown, as well. Namely, observing the anchovy regrutation index during the 1979-1992 period, higher recruitment index was registered in 1988-1990 (CINGOLANI et al., 1996). It can be seen that since the years of 1989 and 1990, the consequence of the anchovy year class strength was further reflected in dependence of the anchovy life span, which is five years (SINOVČIĆ, 1992).

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Neki ekološki aspekti juvenilna brgljuna, *Engraulis encrasicolus* (L.) u estuarnim uvjetima (Novigradsko more - srednji Jadran)

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SAŽETAK

U radu je prikazan ekološki aspekt juvenilna brgljuna, *Engraulis encrasicolus*. Analizirani su uzorci plivarice u razdoblju od kolovoza 1989 do ožujka 1991 - ukupno 2 574 prmjerka u području Novigradskog mora (srednji Jadran). Brgljun je postigao prvu spolnu zrelost pri kraju prve godine života. 50% populacije ove vrste je doseglo prvu spolnu zrelost pri dužini od 9.0 cm, dok je čitava populacija bila spolno zrela kod 11.5 cm. Dužinsko-maseni odnos je imao sljedeće vrijednosti : a =0.0038; b =3.1939 (r^2= 0.99); dobijena je pozitivna alometrija. Parametri rasta juvenilnih primjeraka ove pelagičke vrste su iznosili : $L\infty$ = 13,2 cm; K = 0.82 god^{-1} a vrijednost t_0 = -0.5.