The population dynamics of the juvenile anchovy, Engraulis encrasicolus (L.), under the Estuarine conditions (Novigrad Sea - Central Eastern Adriatic)

Sinovcic G.

in

Lleonart J. (ed.).
Dynamique des populations marines

Zaragoza : CIHEAM
Cahiers Options Méditerranéennes; n. 35

1998
pages 273-282

The population dynamics of the juvenile anchovy, *Engraulis encrasicolus* (L.), under the Estuarine conditions (Novigrad Sea - Central Eastern Adriatic)

G. Sinovčić
Institute of Oceanography and Fisheries, Šet. I. Meštrovića 63, 21000 Split, Croatia

SUMMARY - The population dynamics of the juvenile anchovy *Engraulis encrasicolus* (N = 2,564) was studied using monthly length and weight frequency data (August 1989 - March 1991) from the central part of the Adriatic Sea (Novigrad Sea and Karin Sea). The von Bertalanffy growth parameters were estimated as $L\infty = 13.2$ cm total length, $K = 0.82$ per year and $t_0 = -0.5$. Mortality rates for all fish, estimated from a length converted catch curve were as follows: total mortality was $Z = 1.664$ per year, fishing mortality $F = 0.230$ per year, with natural mortality $M = 1.430$ per year derived from Pauly's empirical formula. Exploitation rate was $E = 0.139$. Fifty per cent maturity was reached at 9.0 cm total length.

Key words: Anchovy, *Engraulis encrasicolus*, population dynamics, Eastern Adriatic.

RESUME - *"Dynamique des populations d'anchois juvéniles,* Engraulis encrasicolus *(L.), sous conditions estuariennes (mer de Novigrad - partie orientale centrale de la mer Adriatique)". La dynamique des anchois juvéniles,* Engraulis encrasicolus *(N = 2 564), dans la partie centrale de la Mer Adriatique (la Mer de Novigrad et la Mer de Karin) a été étudiée en utilisant les données de fréquence de longueur et de poids à partir du mois d'août 1989 jusqu'au mois de mars 1991. Les paramètres de von Bertalanffy ont été estimés, étant les suivants,* $L\infty = 13,2$ *cm de longueur totale,* $K = 0,82$ *par année et* $t_0 = -0,5$*. Les mortalités pour tous les poissons, déduites d'une courbe convertie en longueur étaient les suivantes : la mortalité totale était de* $Z = 1,664$ *par année, la mortalité de pêche* $F = 0,230$ *par année, avec une mortalité annuelle* $M = 1,430$ *par année déduite de la formule empirique de Pauly. Le taux d'exploitation était de* $E = 0,139$*. On a atteint la maturité à 9,0 cm de longueur totale.*

Mots-clés : *Anchois,* Engraulis encrasicolus, *dynamique des populations, Adriatique orientale.*

Introduction

Year class strength is mainly estimated during the first year of life and depends on the conditions for fish reproduction and survival during early stages of ontogeny (Hjort, 1914; Deckhnik *et al.*, 1985).

Since 1967 anchovy landings have decreased greatly without considerable change in fishing effort (Sinovčić *et al.*, 1991; Sinovčić, 1992). This may be related to the decrease of the anchovy population itself or reduced fishermen stimulation for anchovy catch. Many attempts have been made to explain these fluctuations in the variety of ways (Regner *et al.*, 1981; Sinovčić *et al.*, 1991; Sinovčić, 1992; Sinovčić and Alegría-Hernández, 1997).

This paper deals with the well marked relationship between stock and appearance of strong year-class of anchovy, which is some evidence for recruitment dependence on environmental factors.

Material and methods

A total of 2,564 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). Anchovy were caught by purse seines under artificial light, during darks of the moon. Representative anchovy samples were collected monthly between August 1989 to March 1991.

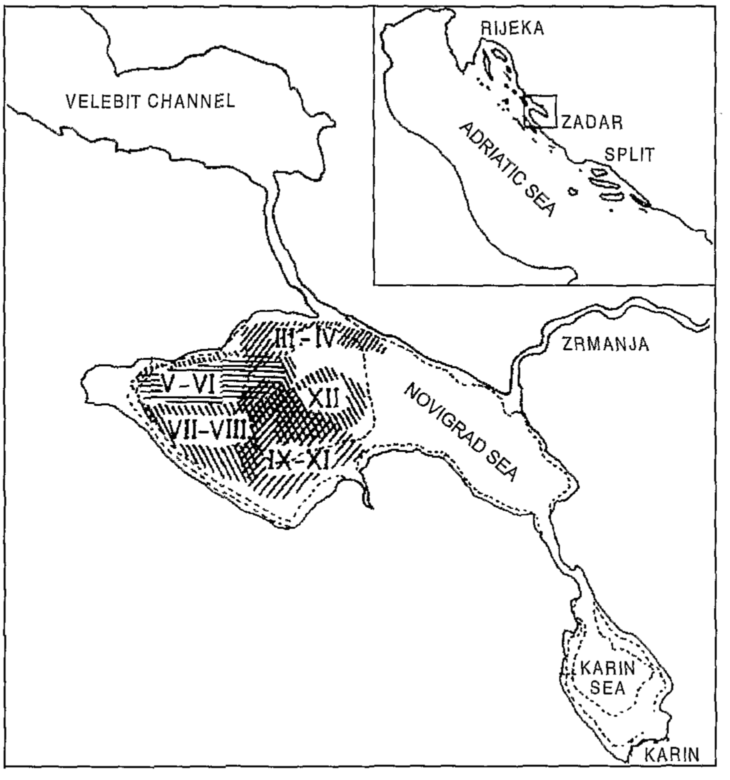

Fig. 1. Map showing the investigation area as well as the space and time distribution of juvenile anchovy in the Novigrad Sea during 1990.

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 fish length were placed in halfentimetre groups. Lower class limits were used.

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, Gompenz model was applied:

$$P(x) = a\, e^{-be^{-cx}}$$

where P is the proportion of mature 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 growth equation parameters L_∞ 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.

The length-converted catch curve procedure of Elefan 2 was used to estimate the total mortality *(Z)* for anchovy.

The natural mortality *(M)* was estimated using the Pauly (1980) empirical formula:

$$\log 10\, M = 0.0066 - 0.279 \log 10\, L\infty + 0.6543 \log 10\, K + 0.4634 \log 10\, T$$

and using a mean annual environmental temperature (T) of 14°C. Fishing mortality (F) was calculated from F = Z-M, and the exploitation rate (E) from E = F/Z, i.e., the fraction of total an mortality (Z) due to fishing mortality (F).

Study area

Bays the Novigrad Sea and the Karin Sea are rather isolated, markedly jagged and complex hydrogeomorphologic system, 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 area of 30 square km with the average depth of 28 meters in the central part area and the water mass of 0.5 cubic km is bigger than the Karin Sea which covers the surface of 5.4 square km and volume of 0.04 cubic km. The isobath of 10 m is very close to the coast (Fig. 1). Both of them are interconnected with the strait which is 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 under the sea surface as deep as 40 m.

Results and discussion

Hydrography

The most important hydrographic parameters which define physical-chemical qualities of the sea and determine distribution and abundance of living organisms are: temperature, salinity and oxygen contents.

Data displayed in Fig. 2 represents the monthly temperature and salinity (thick lines) variations (1 and 5 m) in the bays of the eastern Adriatic during December 1981-November 1982. During the investigation period, the lowest surface temperature of 4.1°C was noted in the Karin Sea in January which is, according to Zore-Armanda (1969), the minimal 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 river Zrmanja bed; it flows off towards the Karin Sea (Fig. 1). The highest surface temperature of 23.2°C was noted in the Karin Sea in June. Ten years later, in 1990, the highest average annual surface temperature amplitude was Δt = 15.2°C, e.g., between the lowest average month 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. These are the residue of the summer water which entered the area from the Velebit Channel by deep sea compensation current.

Nutrients

The values of phosphate which amounted to 0.25 µmol/l and especially silicates, which amounted to 12.8 µmol/l in the Novigrad Sea and 30.8 µmol/l 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.

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 oxidation of organic matter which comes from the mainland. Owing to these facts the area is well aired with a high level of self-purification.

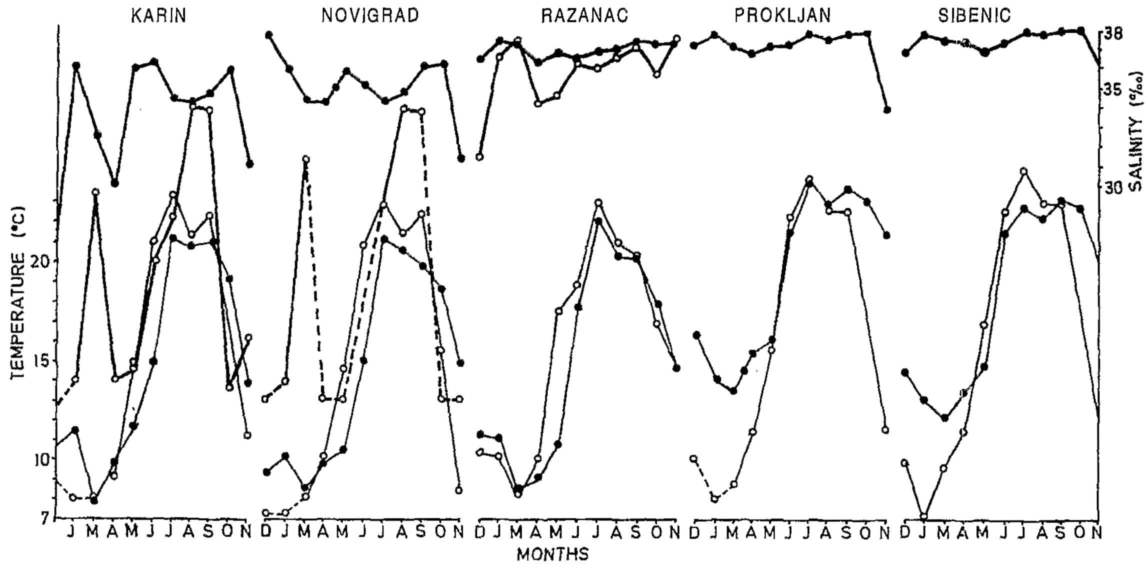

Fig. 2. Seasonal temperature and salinity (thick lines) changes in the bays of the eastern Adriatic coast during December 1981-November 1982 (after: Kršinić, 1987).

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 (‰)	Temperature °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

Biologic parameter

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 existing populations to increase.

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 and the Šibenik harbours are richer. However, high production in these areas is the result of urban eutrophication while the bays Novigrad Sea and the Karin Sea are naturally eutroficated.

South and west afforested coasts are the richest and most productive parts of the area. Together with the rain there also comes the organic matter, enriching the area with the nutrients which fulfills 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 component 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 (Fig. 3). The amounts show that these groups of organisms make this *aquatorium* one of the richest areas which is very important; plankton organisms present basic food for pelagic species.

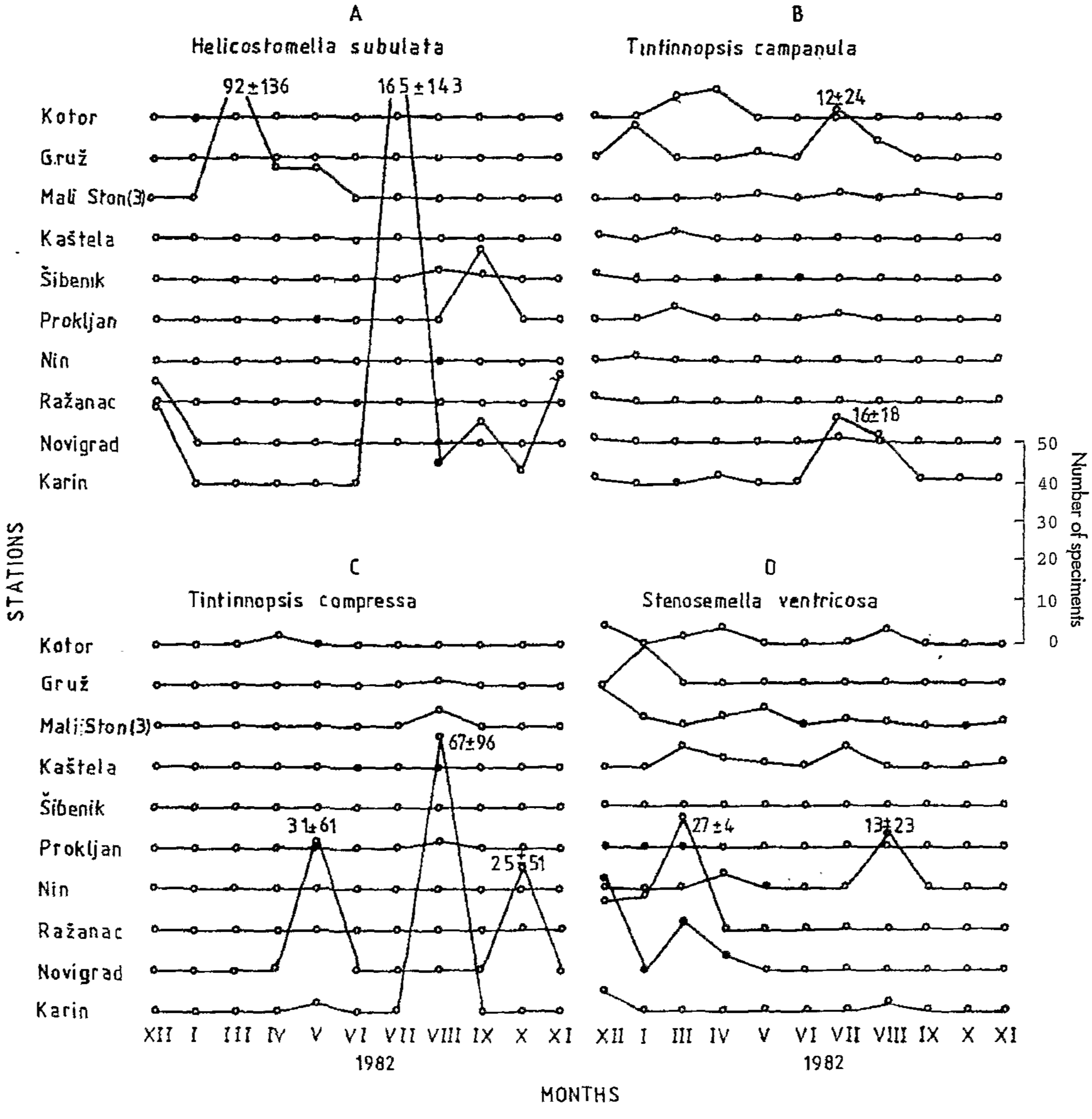

Fig. 3. Appearance of *Helicostomella subulata, Tintinnopsos campanula, Tintinnopsis compressa* and *Stenosomella ventricosa* in some bays of the eastern Adriatic (maximum ± standard deviation) (after: Kršinić, 1987).

Small pelagic fish

Distribution

Due to their position in the trophic chain, small pelagics 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.

Juvenile anchovy retain in the Novigrad Sea all the year round using it as a nursery area. Juveniles remain there before migrating into deeper waters as they increase in size. Data of realized juvenile anchovy catches represented in Fig. 1, simultaneously shows the space and time distribution of juvenile anchovy in this area. In spring the schools of this species are located close to the Novigrad Sea entrance. During summer they spread their presence to the south and the west, afforested and more productive coast of the bay. During autumn they migrate to the deeper waters, but in winter they move to the deepest, central part of the bay, where they find most favourable temperature conditions. 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.

Growth

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. They represented 0 + (98%) and 1 + (2%) age groups. The resulting von Bertalanffy growth parameters 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 von Bertalanffy growth equation of juvenile anchovy is:

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

Growth of the juvenile anchovy are followed with respect to modal lengths which varied from 6.0 cm (August 1989) to 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 (July 1989) and 10.3 cm (March 1990). i.e., between 7.3 cm (July 1990) and 10 cm (March 1991) (Table 2).

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	Range length (cm)	Range weight (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
03.10.1989	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	2.95	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
02.10.1990	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

Modes representing cohorts are shown as length-frequency histograms in Fig. 4.

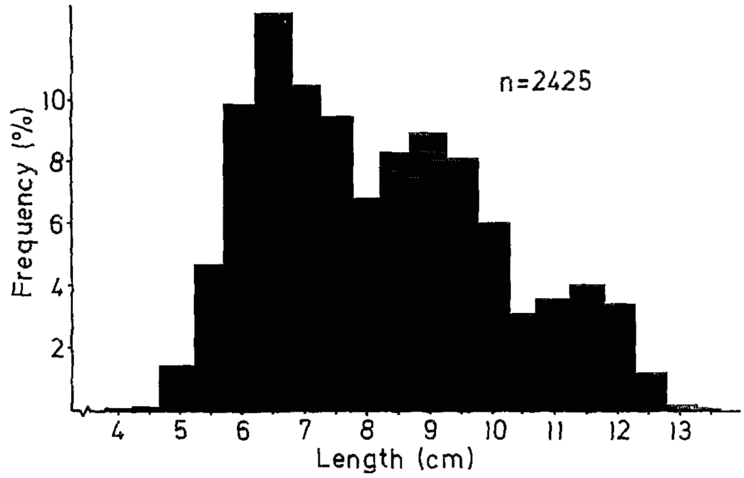

Fig. 4. Size frequency of anchovy (from August 1989 to March 1991).

Figure 5 shows comparison of the achieved anchovy average total lengths in the same months in the successive years (different year classes). There is a higher amount of weight in the 1990 year class of juvenile anchovy, probably due to the strictly scientific control of the optimal amount catches of juvenile anchovy population. Namely, after strong year class occurrence of the anchovy, adapting the controlled catches, its population was reduced to the optimal extent and remaining anchovy population had more available food, more phytoplankton and zooplankton organisms at their disposal. The result of favourable feeding of juvenile anchovy is faster growth.

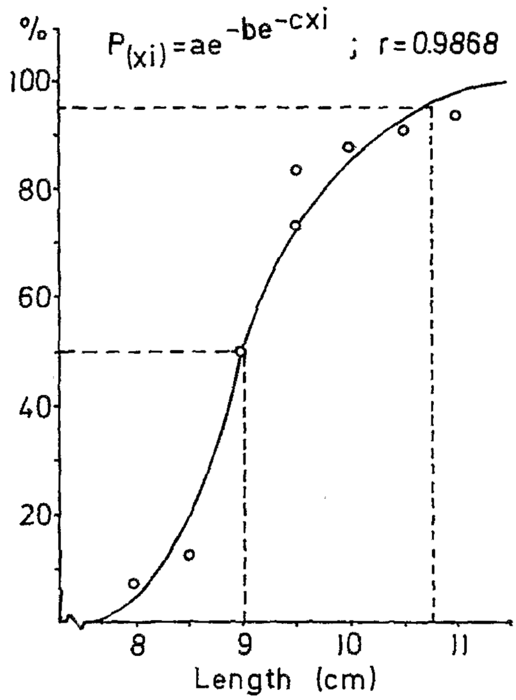

Fig. 5. Percentages of most matured anchovy specimens (maturity stages V and VI) as a function of total length, Novigrad Sea, 1990.

First sexual maturity

Data displayed in Fig. 6 presents the lowest size of sexual maturation from the presence of the most progressive stages of gonads with the lowest lengths on the basis of the Gompenz model. Data depicts that the smallest sample with the signs of sexual activity was a male from the length class of 8.0 cm.

Fifty per cent of the anchovy population becomes mature at the minimal length of 9.0 cm, while 95% of anchovy population becomes mature at the minimal 10.8 cm total length. At the 11.5 cm the whole anchovy population is sexually mature. Highly significant correlation are found (r = 0. 9868).

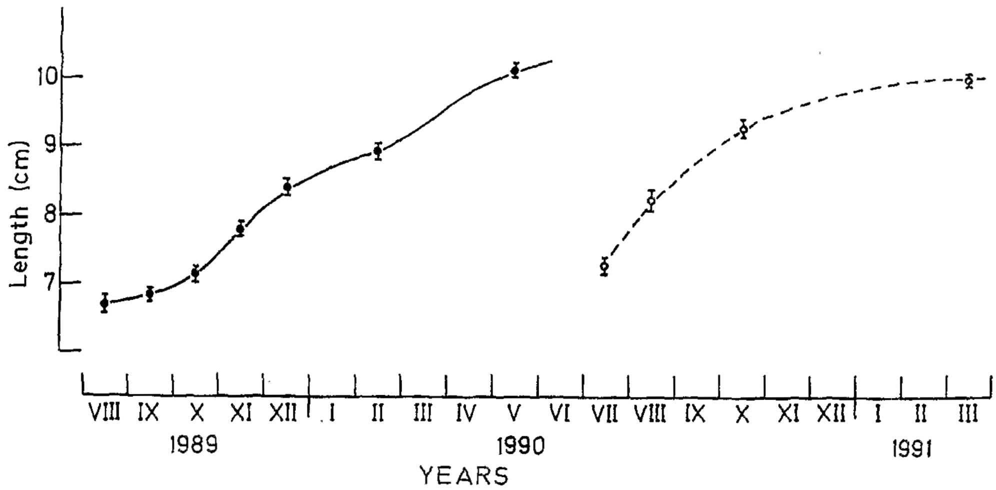

Fig. 6. Variations of average anchovy total length as a function of sampling month and year class in the Novigrad Sea.

During sexual maturation, longer anchovy individuals mature earlier (Fig. 7).

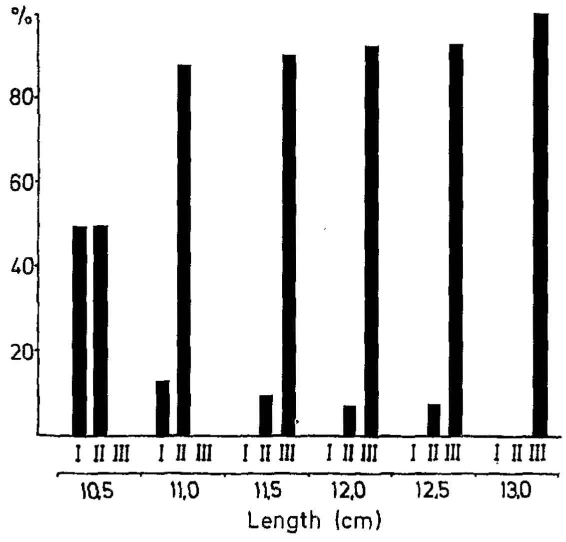

Fig. 7. Variations of anchovy gonad development (percentages of maturity stages) as a function of total length.

Catches

Figure 8 shows how strong age class observed during usual monitoring, influenced the overall catches of this species in the eastern part of the Adriatic. The catches obtained in the western part of the Adriatic and catches in overall Adriatic Sea are shown as well. It can be seen that since the years of 1989 and 1990 when the existence of strong year class was noticed, the anchovy catches have been increased. As the anchovy life span is five years (Sinovčić, 1992), the consequence of the strong year class is still reflected nowadays.

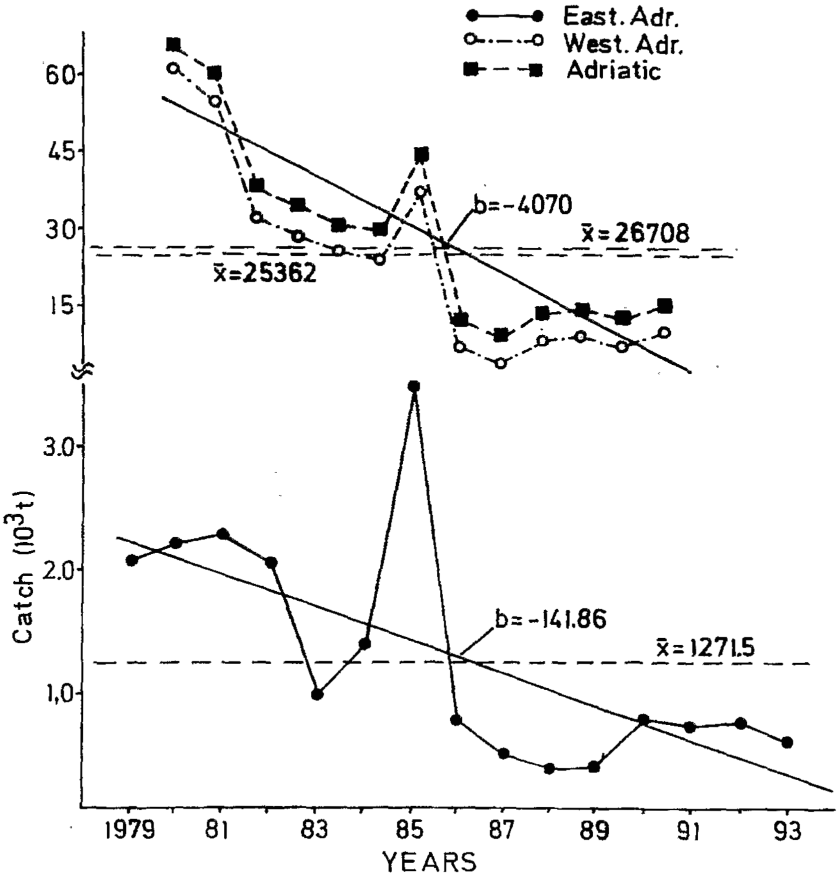

Fig. 8. Fluctuations of anchovy annual catches in the Adriatic during 1979-1993 period.

Conclusions

Juvenile anchovy live, feed and grow in the bays of the Novigrad Sea and the Karin Sea. Furthermore, if more significant recruitment occurs in a year, it could be observed first there. This findings enable us to predict the rich or poor yield in specifical years due to poor or considerable occurrence of the species. When rich year class occurs which denotes the renewal of the populations through the strong recruitment, controlled catches of exactly determined quantities of juvenile anchovies are possible by strictly scientific observations to rule the juvenile anchovy yields in the sense of rational managing of edible, renewable resources. By reducing the population density with optimal fishing, remaining fish population have more food available, feeding of individuals is better and their growth faster. Moreover, the neighbouring sea area is being enriched, both qualitatively and quantitatively, which influences overall catches. In other words, realizing the rational exploitation of marine resources, we contribute to the protection of the natural ecosystem and its resources in general. enabling undisturbed renewal and protect the biodiversity which is very requested today.

References

Buljan, M. (1969). Neka hidrografska svojstva estuatskih podrucja rijeke Krke i Zrmanje. *Krš Jugoslavije,* 6: 303-331 (in Croatian).

Deckhnik, T.V., Serebryakov., V.P. and Soin, S.G. (1985). Importance of early stages of fish development in the year class abundance formation. In: *Teoriya formirovaniya chisllenosti i ratsionalnoga ispolzovaniya promyslovikh ryb.* Nauka Press, pp. 56-72 (in Russian).

Ercegović, A. (1940). Ishrana srdele (*Clupea pilcardus* Walb. u stadiju metamorfoze. *God. Oceanogr. Inst.,* 2: 26-44 (in Croatian).

Gulland, J.A. (1969). Manual of methods for fish stock assessment. Part I. Fish population analysis. *FAO Man. Fish. Sci.,* 4: 70.

Hjort, J. (1914). Fluctuations in the great fisheries of Northern Europe viewed in the light of biological research. *Rapp. P-v. Reun. Cons int. Explor. Mer,* 5(20): 1-228.

Kršinić, F. (1987). Tintinnines (*Ciliophora, Oligtrichida, Tintinnina)* in Eastern Adriatic Bays. *Estuarine Coastal and Shelf Science,* 24: 527-538.

Pauly, D. (1980). On the interrelationships between natural mortality. growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons int. Explor. Mer,* 39: 195-212.

Regner, S., Piccinetti, C., Specchi, M. and Sinovčić, G. (1981). Preliminary statistical analysis of sardine stock estimation from data obtained by egg surveys. *FAO Fish. Rep.,* 253: 143-154.

Sinovčić, G. (1978). On the ecology of anchovy *Engraulis encrasicolus* (L.) in the central Adriatic. *Acta Adriat.*, 19(2): 32.

Sinovčić, G. (1992*). Biologija i dinamika populacije brgljuna. Engraulis encrasicolus (Linnaeus, 1758) u Jadranu.* PhD Thesis, Faculty of Science, University, Zagreb, p. 163 (in Croatian).

Sinovčić, G. and Alegría-Hernández, V. (1997). Variation in abundance and size of the sardine, *ardina pilchardus* (Walbaum) in the eastern Adriatic. *Oceanologica Acta* (in press).

Sinovči, G., Alegría-Hernández, V. and Jardas, I. (1991). Biološka osnova pelagijskog i priobalnog ribolova Jugoslavije. *Pomorski zbornik*, 29: 383-408 (in Croatian).

Škrivanić, A. and Barić, A. (1979). Cruises of the research vessel "Vila Velebita" in the Kvarner of the Adriatic Sea. IV. Distribution of the primary nutrients. *Thalassia Jugosl.,* 15: 61-88.

Viličić, D. (1989). Phytoplankton population density and volume as indicators of eutrophication in the eastern part of the Adriatic Sea. *Hydrobiologia*, 174: 117-132.

Zore-Armanda, M. (1969). Temperature relations in the Adriatic Sea. *Acta Adriat.*, 13: 1-50.