ISSN: 0001-5113
AADRAY

ACTA ADRIAT.,
41 (1): 3-53, 2000

UDC: 597.5(262.3):639.222.6
Original scientific paper

Anchovy, *Engraulis encrasicolus* (LINNAEUS, 1758): biology, population dynamics and fisheries case study

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The biological and population dynamics parameters, population structure, length and age distrubution, sex ratio, reproduction, age and growth, mortality, migration, estimation of population size and maximum sustainable yield as well as exploitation of the anchovy , Engraulis encrasicolus *(n = 20 910) were studied from sampling undertaken in the Middle and partly in the North Adriatic Sea (Dalmatia) during 1974-1990 period. The overall anchovy length from both the coastal and the open sea water samples ranged between 7.5 and 18.7 cm. Samples of catches from the open sea waters comprised the anchovy of greater mean lengths than those from the coastal waters. The differences in mean lengths between sexes were small. The overall ratio of male and female was almost 1:1.*

Spring months represent prematurity and summer months the period of anchovy maximum sexual activity. Winter is the inactivity period in its sexual cycle. In the prematurity stage male gonads were found to be in slightly more advanced stages than those of females.

Anchovy started to spawn earlier in the open sea waters and reached the spawning maximum sooner than in the coastal waters. Female gonad weight values as well as the values of gonosomatic index were greater than in males. Sexual evolution in bigger anchovy specimens from the open sea waters took place earlier than in smaller ones from the coastal water areas.

The length-weight relationship for all fish was described by the following parameters: a = *0.0040* ; b = *3.0.*

Anchovy aged 0 to 4+ years old were present in the samples. Age groups 1+ and 2+ were the most prominent. They reach the asymptotic length of 19.4 cm. The fastest growth in anchovy occurs during the first three years of life. The von Bertalanffy growth parameters for all fish were $L_\infty = 19.4$ *cm;* $W_\infty = 34.8$ *g ;* $K = 0.57$ *yr* $^{-1}$ *and* $t_0 = -0.5$ *yr*$^{-1}$.

Overlapping of lengths are most evident in age groups 2+ and 3+.

The highest total mortality rate (Z) was found in the youngest anchovy individuals, whereas their survival rate was the lowest . The average annual mortality (A) was 61 %. The relatively high total mortality coefficient value Z = *1.183 is evident. Natural mortality of anchovy population is M = 0.65. Fishing mortality (F= 0.53) has a lesser influence on total mortality. The exploitation rate was E = 0.45.*

The estimation of anchovy population size and maximum sustainable yield (MSY) shows that this species could have been exploited more than they had been exploited in some years of the investigation period.

Key words : Anchovy, Adriatic, biology, population dynamic, fisheries

INTRODUCTION

Anchovy, *Engraulis encrasicolus* (LINNAEUS,1758), is an endemic species of the Mediterranean-Atlantic region (ERCEGOVIĆ, 1949) and the European only representative of the Engraulidae family. It belongs to the group of small pelagic fish that contribute more than 50% to the overall catches from the Mediterranean, Black Sea and Adriatic Sea (FAO Fish. Rep. 426).They are caught along the Mediterranean shores, also reaching the shores of Africa and Asia. In the East Atlantic they occur from the west coast of Africa to Skagerrak, Kattegat and the British Isles.

Anchovy is a pelagic species, widely spread in the Adriatic Sea. It inhabits bays, channels and open sea, from the Gulf of Trieste to the Otranto Strait with the exception of the greatest depths. They are caught mainly within spring-autumn period. In the same regions they are located in greater depths during winter, since they are often found in the catches from the trawl.

Anchovy is a species of a special economic value in all parts of the Mediterranean Sea. They play an important role in the Croatian fishing industry in spite of the relatively small catch. Namely, the mean annual catch value for the period from 1947 to 1988 was 2115.5 tons (s = 1 495.1217 t) with an evident annual catch variation (V = 70.81 %) and a slight tendency to increase (b = 27.344 t).

In spite of the considerable economic importance of this species, its wide distribution and market demand, the knowledge of its biology and population dynamics has been mainly fragmentary and insufficient so far. It is especially true of the juvenile and adult phases biology and population dynamics of the anchovy. So far researches have been aimed more to the planktonic phase of development in this pelagic species.

Studying biology and population dynamics of anchovy which is subject to frequent and evident natural fluctuations, is important not only because of the insufficient knowledge but also because of anchovy population management.

Scientific reasons which led to the research of biology and population dynamics of anchovy originate from the fact that the population of *Engraulis encrasicolus* makes a considerable component of pelagic community in the Adriatic Sea and is of considerable meaning for Croatian sea fishery and fishing industry. The main aim of the research was to study the characteristics of anchovy population. This particularly refers to morphological research for a more complete diagnosis of the population by analysing morphometric characteristics.

In the research into biology and population dynamics of anchovy, special attention was paid to studying their migrations, population structure considering length, sex and age, growth, reproduction, mortality and survival. At the end, an estimation of the anchovy population size was made as well as that of maximum sustainable yield (*MSY*).

The abundance and stock size of anchovy depends on considerable natural fluctuations. They are a consequence of complicated interactions between the population and its environment. Due to its position in the trophic web, the anchovy population reacts promptly to the increase in primary production of organic matter in the sea. Therefore, the anticipation of the natural fluctuation of specimen abundance, especially discovering their causality together with studying population dynamics, falls among the main tasks of fishery biology. A fish population is exposed to the activities of various factors that influence its stock size, as well. It is primarily relevant to natural mortality as a consequence of the activities of unfavourable environmental factors, but also of illness, starvation, parasitism, predation and senility. Fishing mortality of a fish population is dependent on the fishing degree.

Assessing the size of the anchovy population and the maximum sustainable yield (MSY) are the main goals of biology research in the Adriatic Sea.

The research results, as we hope, bring about the better knowledge of fishery biology and population dynamics of anchovy in the Adriatic Sea.

STUDY AREA

The research material was mainly obtained from Kaštela Bay (the most inshore coastal waters) and the region around the islands of Vis and Biševo (open sea waters) (Fig. 1). Between these regions there are differences in depth, in the distance from the land as well as in ecological factors.

Kaštela Bay area covers 62 km^2 and its mean depth is 23 m (ZORE - ARMANDA, 1975). The renewal of water in Kaštela Bay occurs twice a month (ZORE-ARMANDA, *ibid.*). The influence of the inshore current is slightly stronger than that of the offshore one (BULJAN and ZORE-ARMANDA, 1966). The bay is shallower in its West and North-West part and is the deepest in the middle, where its depth is 42 m.

Kaštela Bay is characterized by great oscillations of hydrologic factors caused by the vicinity of land, small depth and a flow of fresh water from the Jadro River and by underwater springs.

The mean surface temperature obtained after a few years research ranges from a minimum of 7°C (February) to 25.05° C (August)

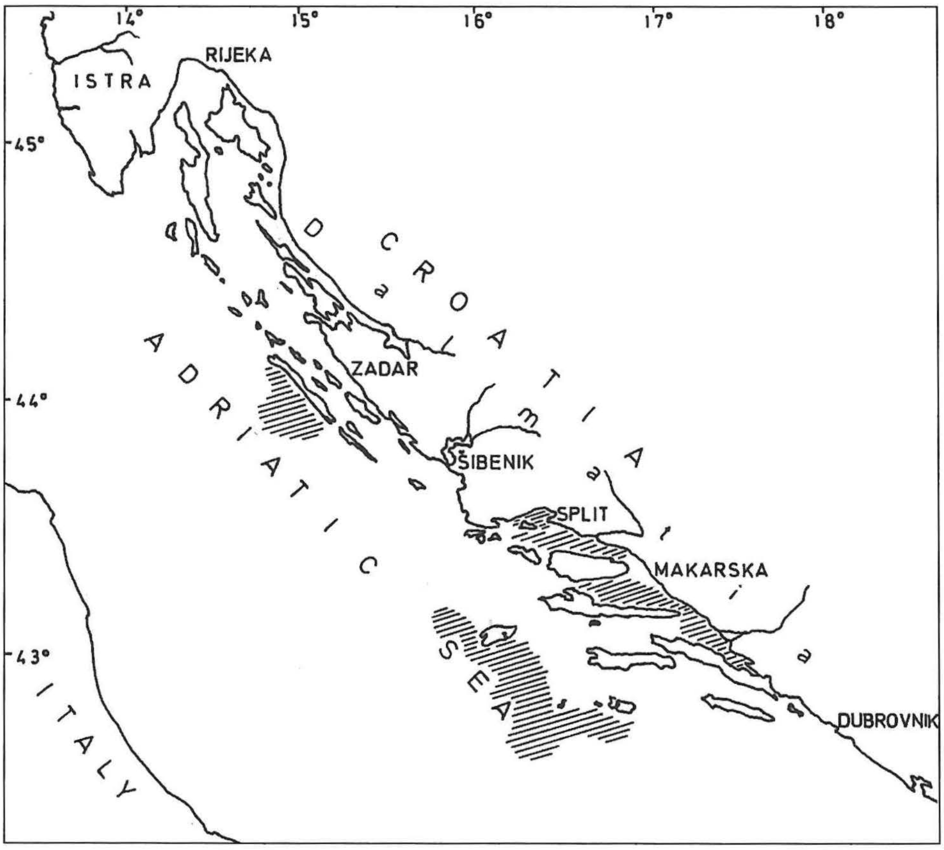

Fig.1. Study area

and at the depth of 30 m from 12.0°C (February) to 22.2° C (October) (BULJAN and ZORE-ARMANDA, 1971). Similar values were obtained by VUKADIN (1991) within eight years period (Fig.2).

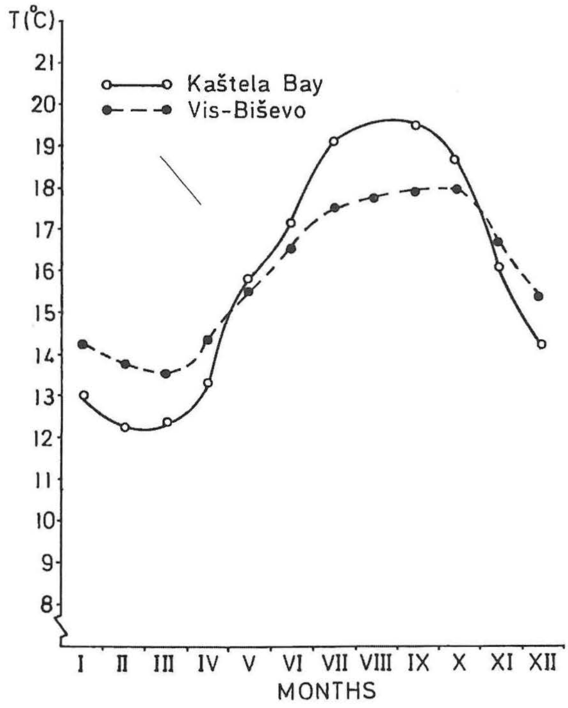

Fig. 2. Monthly fluctuations of surface temperature (°C) in Kaštela Bay and in the region of Vis and Biševo Islands within 1970 - 1977 period (VUKADIN, 1991)

The same authors (BULJAN and ZORE-ARMANDA, 1979) obtained the mean salinity values in the bay : 33.3 psu (August) on the surface and from 34.6 psu (December) to 38.0 psu (September) in a 30 m water column.

The sea currents are of very changeable directions due to the shallowness of Kaštela Bay, weak tidal currents and strong local winds. The main resultant current speed is 6 cm sec^{-1}, 4 m sec^{-1} in the intermediate layer, while in the bottom layer it is 3 m sec^{-1} (BULJAN and ZORE-ARMANDA, 1971). The current is very strong in autumn and winter. During spring and summer the resultant N - NW current is predominant. It is particularly prevalent in the surface layer. The resultant S current is predominant in winter (ZORE - ARMANDA, 1974).

Measurings of primary productivity by C^{14} method show an oscillation of values from year to year ranging between 103.2 and 117.4 g C m^{-2} with maximum values in winter and spring (PUCHER - PETKOVIĆ, 1970). There has also been spring maximum lately (PUCHER - PETKOVIĆ, 1975; PUCHER - PETKOVIĆ and MARASOVIĆ, 1980).

Based on long-term observations VUČETIĆ (1971) stated that the mean value of a zooplankton quantity (dry weight) is from 7.7 mg m^{-1} up, with maximum values during the warmer period of the year, that is, in March, May and August.

The region of Vis and Biševo Islands is far from mainland shores and widely open towards high seas, so it is under a strong influence of the open sea. Near the islands there is a 100 m isobath. The region of Vis and Biševo Islands is characterized by considerably smaller fluctations of hydrologic factors compared to coastal waters.

The mean surface temperature in the period from 1947 to 1963 ranged from 13.5 °C (February) to 23.9 °C (August), from 13.4 °C (February) to 19.8 °C (October) at the depth of 20 m, and from 13.5 °C (February) to 18.5 °C (November) at the depth of 60 m (BULJAN and ZORE - ARMANDA, 1966).

The mean salinity value in the period from 1947 to 1963 fluctuated on the surface from 37.7 psu (May) to 38.5 psu (October), from 38.2 psu (July) to 38.6 psu (October) at 20 m depth and from 38.3 psu (February) to 38.7 psu (October) at 60 m deep (BULJAN and ZORE-ARMANDA, 1966).

In the open sea area of the Middle Adriatic the N-W surface current is prevalent in winter, N in spring, SE in summer and SW in autumn. In the intermediate layer E current direction is the most evident although the W and NW direction speeds are the greatest. In the colder part of the year S current direction prevails in the bottom layer what is probably caused by the outflow of colder bottom sea water that flows along the bottom from coastal waters towards open sea. In the warmer part of the year a periodical interchange of W and SE current directions was recorded. The speed of surface current oscillates between 1-14 cm sec^{-1} and between 5-13 cm sec^{-1} in the intermediate layer, while in the bottom layer it is 3-16 cm sec^{-1} (ZORE-ARMANDA, 1968).

Primary production of organic matter varies from year to year, between 44.4 to 92.2 g C m^{-2}, (PUCHER-PETKOVIĆ and ZORE-ARMANDA, 1973). Maximum values in organic matter production were recorded in winter (December, January) and in spring (May -June).

Zooplankton biomass is, on an average, 3.8 mg of dry matter per cubic metre. Higher dry weight values in zooplankton quantity were recorded from March to May with an outstanding maximum in April (VUČETIĆ, 1971).

Therefore, in Kaštela Bay during warmer time of the year higher values of phytoplankton density were recorded and lower values of zooplankton biomass (KARLOVAC *et al.*, 1974; VUČETIĆ, 1975; PUCHER-PETKOVIĆ and MARASOVIĆ, 1980) than those in the area of Vis and Biševo Islands. In Kaštela Bay plenty of small copepods (GAMULIN, 1964; VUČETIĆ, 1975) and decapods (VUČETIĆ, *ibid.*) were registered in that time of the year.

The long-term observations of all the stations of the study area show that salinity and nutrient quantities are periodically increased what produces favourable effects for the primary and secondary organic production in the whole Adriatic (PUCHER-PETKOVIĆ and ZORE-ARMANDA, 1973). These salinity and production relation changes are due to periodical intensified ingressions of the more saline eastern Mediterranean water into the Adriatic (BULJAN, 1974).

MATERIAL AND METHODS

Samples of anchovy catches are mainly obtained from Kaštela Bay (coastal waters) and from the region of Vis and Biševo Islands (open waters). In this region anchovy are caught only by purse seines, under artificial light, during darks of the moon. The samples of anchovy catches were obtained mainly directly from fishermen, only a small number of samples was taken from the fish market.

Representative samples were used to study length and age composition of the catch as well as the composition regarding sex, growth, gonad state and partly gonad weight and gonosomatic ratio. We took randomly approximately 100 specimens per sample.

Data on fish length in millimetres refer to total length and were placed in halfcentimetre groups. They were reduced to the lower limits of the length class. Mean values were corrected. Standard length of anchovy was used only while studying the relationship between that length and total length.

For the morphological analysis, anchovy body dimensions were measured on fresh material. The accuracy was 0.01 mm. The seven body dimensions shown in Fig.3 were analysed:

L_T - Total length : from the beginning of the rostrum to the end of the tail
L_S - Standard length : from the beginning of the rostrum to the end of the body
L_A - Preanal length : from the beginning of the rostrum to the beginning of the anus
L_C - Head length : from the beginning of the rostrum to the very end of the operculum
L_O - Preorbital distance : from the beginning of the rostrum to the front rim of the eye cavity
O-O' - Diameter of the eye
BH - Body height

All measured body dimensions were compared to the adequate total body length in order to obtain relative relationships expressed in per-

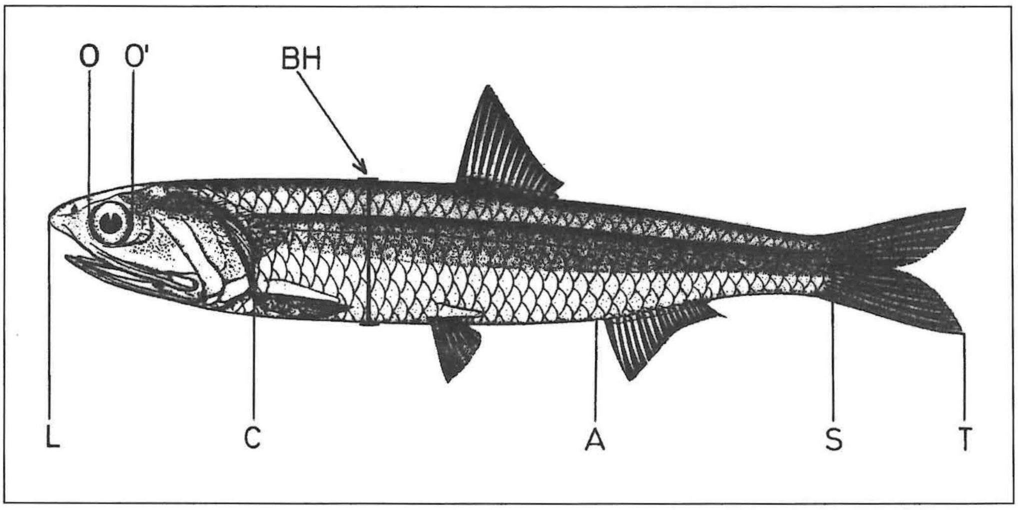

Fig.3. Schematic drawing of anchovy body with measured dimensions

cent. Out of statistical methods the central tendency and variability measures were used.

To study the differences in male - female distribution of anchovy, samples of commercial catches from coastal waters (Kaštela Bay) and open sea (the region of Vis and Biševo Islands) of the Middle Adriatic were used. The samples of catches comprised 2401 anchovy specimens, out of which 1181 (49.2 %) were males and 1220 (50.8 %) females.

Data on length and age distribution of anchovy were being collected in the period from 1974 to 1981 inclusive. In those surveys samples of catches from 1990 were comprised. Commercial samples of small pelagic fish caught by purse seine in the coastal and channel waters as well as in the open sea of the Adriatic were also used. The sexual cycle of anchovy was studied on the basis of the stages of gonad development, the fluctuations of gonad weight and gonosomatic ratio (gonosomatic index - GSI). The body was weighed together with stomach content. Body weight is expressed with 0.1 g accuracy and gonad weight with 0.01 accuracy.

Sex was determined macroscopically considering shape, look and gonad structure. Determining sex was not a problem with the exception of the smallest specimens in inactive period of sexual cycle, in which case it was not possible to determine sex in the course of routine analysis. In such specimens sex was determined microscopically.

Gonad state of anchovy was recorded macroscopically considering size, colour and look of gonads. We used the empiric scale described by SINOVČIĆ (1978) which, with certain modifications has this form:

Stage I - Gonads are very small and transparent. Such can be seen only in specimens that have not reached their first maturity

Stage II - Gonads fill slightly less than half of the visceral cavity. Eggs can not be observed by the naked eye.

Stage III - Gonads fill more than half of the visceral cavity. Eggs can be observed by naked eye.

Stage IV - Gonads fill about two thirds of the visceral cavity. Eggs are opaque. Testicles are white.

Stage V - Gonads fill the whole visceral cavity. Testicles are creamy white. Ovaries are light red. Eggs are opaque.

Stage VI - Gonads are fully ripe. Milt and eggs are extruded with a pressure on the abdomen. Eggs are hyaline.

StageVII - Fish have spawned. Gonads are slack and infected with blood.

To determine the anchovy sexual cycle in detail, the gonad weight values and the gonosomatic index were plotted. The weight of the fish body was expressed with the accuracy of 0.1 g. and the gonad weight with the accuracy of 0.01 g.

While studying growth, estimation of age in every individual fish is the basic starting point. Different methods are used in the process. We chose to read age or annual rings on the biggest sagitta otolith.

Section of the fish head has been made with a cross - cut in the middle between the posterior margin of the eye socket and the posterior of the operculum. Both otoliths with the base on the lower part of the skull were removed .

A certain time later the otolith was coloured by method described by SINOVČIĆ (in LEVI and MORTERA, 1981).

Reding growth zones on the anchovy otolith was done on dorsoventral part of the concave side. Since the fastest growth of anchovy is evident on the anterior or posterior part (PANNELLA, 1974), reading on the above - mentioned parts of the otolith would not be valid in determining age in anchovy.

Reading was done in a dark room with a narrow ray of side light. The age of anchovy was determined by hyaline and opaque rings on the sagitta otolith, where the periodical anchovy growth is evident. In case of doubt we would use the reading technique with light coming from below, through a glass stand where the otolith immersed in water was placed on a slide. This rendered the hyaline ring dark and the opaque ring light. The smallest magnification of a binocular microscope was used. After a certain time reading of the same otoliths would be repeated.

We observed that the growth of anchovy otoliths started by formation of the otolith nucleus which can be light or dark, depending on whether the otolith belonged to a specimen produced by an earlier or a later spawning season parental stock. A clear hyaline nucleus indicated that the specimen is produced by an earlier spawning parental stock, whilst an obscure or opaque nucleus indicated a specimen originated from later spawning parent. A wider opaque ring came after, then a hyaline ring. In the case of an additional marginal opaque ring besides the stated ones, we would assign it to 1+, which means that it belonged to a specimen with the completed one year, on the other words the one in the beginning of its second year of life. According to our interpretation an otolith without an opaque marginal ring was in its first year of life and was assigned to 0+. Therefore, an opaque nucleus with a following hyaline ring and an opaque ring after it, and a marginal, barely started hyaline ring was assigned to 1+. In older anchovy specimens the same rule was applied. Namely, one winter (hyaline) and one summer (opaque) ring were interpreted as one completed year of anchovy life.

Age data relate to the total length of anchovy expressed in centimetres with the accuracy of 0.1 cm. Length class values relate to their mean length values.

Samples were analysed statistically. Mean values ($\bar{x}$), the mean standard error (*S.E.*), 95% confident limit of arithmetic mean (*c.l.*), standard deviation (s), variability coefficient (V), regression constant (a), regression coefficient (b), correlation coefficient (r), and determination coefficient (r^2) were estimated. The length and weight growth of anchovy was plotted by the von BERTALANFFY equation (1938), which was modified to this (BEVERTON and HOLT, 1957) :

$$l_t = L_\infty [1 - e^{-K(t-t_0)}] \qquad (3.1.)$$

$$w_t = W_\infty [1 - e^{-K(t-t_0)}]^b \qquad (3.2.)$$

where L_∞ and W_∞ are asymptote length (L_∞) and weight (W_∞) values, K = species growth coefficient, t_0= theoretical age of the fish at the length l_0, that is the age when the formation of otoliths, which are used to estimate age, starts.

Value t_0 was plotted by the expression:

$$t_0 = t + 1/K \ln (L_\infty - l_t)/ L_\infty \qquad (3.3.)$$

The intersection of regression lines and the abscissa gives a value of t_0.

Allometric relationship between length (L) and weight (W) of anchovy was estimated by GM functional regression (RICKER, 1975):

$$\log W = \log a + b \log L \qquad (3.4.)$$

Values of mortality rates were also plotted: total (Z), natural (M) and fishing mortality (F), by the BEVERTON and HOLT equation (1957):

$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L'} \qquad (3.5.)$$

where K and L_∞= constants from the von BERTALANFFY growth equation, $\bar{L}$ = mean length of anchovy in an age group, while L' = the smallest anchovy length in the sample.

The instantaneous rate of natural mortality was plotted by the TAYLOR (1959) expression:

$$M = 0.996/A_{0.95} \qquad (3.6.)$$

and by the RICHTER -EFANOV one (1976):

$$M = \frac{1.521}{X^{0.72}} - 0.155 \qquad (3.7.)$$

where A = the age at which the species reaches 95% level of asymptotic length, X = the age at which the majority of the stock reaches full sexual maturity.

The instantaneous rate of fishing mortality (F) calculated by means of difference between total (Z) and natural (M) mortality:

$$F = Z - M \qquad (3.8.)$$

while the survival rate (S) was calculated by the expression (GULLAND, 1955):

$$S = e^{-Z} \qquad (3.9.)$$

Exploitation rate (E) of anchovy stock was plotted by the equation (BEVERTON, 1963):

$$E = F/(F+M) \qquad (3.10.)$$

The anchovy stock size was estimated by means of VPA method (Virtual Population Analysis) (JONES, 1981) and maximum sustainable yield optimum catch by the expression proposed by CADIMA (after TROADEC, 1977):

$$MSY = Z_t \, . \, 0.5 \, . \, B_t \qquad (3.11.)$$

where Z_t = instantaneous rate of total mortality in year (t); B_t = stock size in respective year.

RESULTS AND DISCUSSION

Biological and population dynamics parameters

Morphometric characteristics

For the morphological analysis 2834 individuals of both sexes from Dalmatian coastal waters and the open sea were used. Total weights of the individuals analysed ranged between 5.3 and 17.7 cm. Mean length of all the individuals analysed was 13.0 with a standard arithmetic mean error of 0.0051.

In many papers on anchovy, standard body length (L_S) is often used instead of its total length (L_T). To make comparison possible we plotted the total length conversion coefficient into standard length and *vice versa*.

Anchovy specimens were placed into three groups: small, medium and large. Small anchovy were less than 8.5 cm total length, medium ranged between 8.6 and 13.0 cm inclusive total length, and large anchovy were over 13.0 cm.The relationship between standard and total length in given groups was as follows:

small anchovy:
$L_T = 0.4764 + 1.1033\ L_S$; $r = 0.9988$; $s_{LT} = 0.8565$; $S_{LS} = 0.9007$

medium anchovy:
$L_T = 0.6448+1.1079\ L_S$; $r = 0.998$; $s_{LT} = 1.1254$; $S_{LS} = 1.1848$

large anchovy:
$L_T = 0.9012 + 1.0902\ L_S$; $r = 0.9998$; $s_{LT} = 1.3167$; $S_{LS} = 1.1984$

or:

small anchovy: $L_S = 0.9021\ L_T - 0.4024$

medium anchovy: $L_S = 0.9019\ L_T - 0.5750$

large anchovy: $L_S = 0.9164\ L_T - 0.8124$

As it has been shown on Table 1, the conversion factor of total length into standard length increases as the fish grow, which points to the fact of proportional reduction of tail in larger anchovy.

The mean *head length* (L_C) of anchovy specimens ranged between 1.3 and 3.5 cm. Their total body length means were between 5.5 and 17.5 cm. Its percentage regarding the total body length of anchovy varied between 20.8 and 23.6 %. The mean head length was 2.174 cm (s = 0.5179; *S.E.* = 0.0097)(Table 2). No differences in head length between sexes were recorded.

The relationship between the anchovy head and its total body length can be expressed by the following equation:

$$L_C = 0.2859 + 0.1888\ L_T$$

where L_C = head length, and L_T = total body length of anchovy. Correlation between these two parameters is very high and significant ($r = 0.9981$; $P<0.001$).

Specimens of anchovy between 5.5 and 17.5 mean total length have shown fluctuation in mean *preanal length* (L_A) of between 3.1 and 8.5 cm, and its percentage in the total body length of anchovy ranged between 53.3 and 56.4 %. Mean preanal length was 5.52 cm (s= 1.5456; *S.E.* = 0.0290) (Table 3). There were no differences in the preanal length between sexes.

Table 1. Conversion factor of standard length (L_S) and total length (L_T) of anchovy

Total length (cm)	Conversion factor	
	L_S into L_T	L_T into L_S
< 8.0	1.1033	0.9021
8.1 – 13.0	1.1079	0.9019
> 13.0	1.0902	0.9164

Table 2. Head length of anchovy. The mean ($\bar{x}$) is presented with 95% confidence limit (c. l.), s is standard deviation and S.E. is mean standard error

Number of specimens	$\bar{x} \pm c.\ l.$ (cm)	s	$S.\ E.$	L_C / L_T (%)
2832	2.17 ± 0.0190	0.5179	0.0097	21.7

The relationship between the total length of anchovy and its preanal length can be described by this expression:

$$L_A = 0.5639\ L_T - 0.1175$$

where L_A = preanal length and L_T = total length of anchovy. Correlation between these two parameters is very high and significant ($r = 0.9991$; $P < 0.001$).

The mean *preorbital length* (L_O), that is the length between the tip of the rostrum and the eye socket in specimens with mean total body length of between 5.5 and 17.5 ranged between 0.3 and 0.8 cm. The percentage of this length in the total length was between 4.2 and 5.5 %. Its mean was 0.46 cm (s=0.01179; $S.E.$= 0.0021) (Table 4). There were no differences in the preorbital length between sexes.

The relationship between this length and the total body length of anchovy can be described by the following equation:

$$L_O = 0.0417\ L_T + 0.0456$$

or

$$L_O = 0.2200\ L_C - 0.0152$$

if the preorbital length is observed related to the head length of anchovy (L_C). The correlation between preorbital length and total length is very high and significant ($r = 0.9697$), same as between preorbital length and head length of anchovy ($r = 0.9665$; $P<0.001$).

The mean *eye diameter* (*0-0'*) of anchovy specimens with mean total body length of between 5.5 and 17.5 cm, ranged between 0.42 and 0.90. These values contributed between 4.2 and 7.6%. If we consider the percentage of eye diameter related to head length, it ranges between 25.9 and 33.3%. The mean eye diameter was 0.62 cm (s = 0.1158; $S.E.$= 0.0022)(Table 5). There were no differences in the eye diameter between males and females. The relationship between the eye diameter and the total body length of anchovy can be described by the following equation:

$$0\text{-}0' = 0.2140 + 0.0409\ L_T$$

or

$$0\text{-}0' = 0.1508 + 002173\ L_C$$

if the eye diameter (*0-0'*) is regarded in relation to the head length of anchovy (L_C).

The correlation between the eye diameter of anchovy and body length on one hand as regards the head length on the other is very high and significant (r = 0.9679, and 0.9672 inclusively; $P<0.001$).

Body height (*BH*) of anchovy specimens with mean total body length of between 5.5 and 17.5 cm ranged between 0.6 and 2.1 while its percentage in total body length ranged between 10.9 and 15.7 %. The mean body height of

Table 3. Preanal length in anchovy. The mean ($\bar{x}$) is presented with 95% confidence limit (c.l.)

Number of specimens	$\bar{x} \pm$ *c. l.* (cm)	*s*	*S. E.*	L_A / L_T (%)
2834	5.52 ± 0.0568	1.5456	0.0290	55.1

Table 4. Preorbital length of anchovy. The mean ($\bar{x}$) is presented with 95% confidence limit (c.l)

Number of specimens	$\bar{x} \pm$ *c. l.* (cm)	*s*	*S. E.*	L_O / L_T	L_O / L_C (%)
2834	0.46 ± 0.0041	0.1179	0.0021	4.6	21.20

Table 5. Eye diameter of anchovy. The mean ($\bar{x}$) is presented with 95% confidence limit (c.l.)

Number of specimens	$\bar{x} \pm$ *c. l.* (cm)	*s*	*S. E.*	*0-0'* / L_T (%)	*0-0'* / L_C (%)
2834	0.62 ± 0.0043	0.1158	0.0022	6.2	28.6

anchovy was 1.38 cm (s = 0.4995; $S.E.$= 0.0094) (Table 6). There were no differences in body height values between sexes.

The relationship between body height and total length of anchovy can be expressed by the following equation:

$$BH = 0.1793\ L_T - 0.3681$$

where BH = body height and L_T = total body length.

The correlation between these two parametres is very high and significant (r = 0.9899; P<0.001).

Data on analysed body dimensions of anchovy with the total length of between 5.5 and 17.5 indicate the slightest changes in eye diameter and preorbital length related to their total length - only 0.5 cm. In the same individuals, preanal length underwent the greatest changes (Table 7). If the proportionality of increase or decline of certain dimensions percentage in the function of total length of anchovy is observed, the greatest fluctuations can be seen in the changes in body height with relation to total length, while the smallest proportional change has been recorded in preorbital length (1.3%).

Considering the parameters of growth in anchovy presented in the chapter on growth, it can be seen that this species grows relatively fast. Growth rate evidently defines body shape, alterating partly the rate of changes. A relatively faster growth results in a proportionally larger head (HUXLEY, 1932).This fact was recorded for the Adriatic anchovy on the basis of our research. Namely, the percentage of head in the total body length in all studied length classes averaged 21.7% , ranging between 20.8 and 23.6%.

Every growth period can be recognized by the characteristics of relative growth of a body part. Gradual decline can be seen in almost all body dimensions of anchovy except in the percentage of body height in the function of its total length, which value tended towards a gradual and a very slight increase. It is evident that the environment can change acceleration or deceleration of growth rate, along with the shape of the fish, or their mortality thus operating selectively, but the frame and direction of such changes having been caused by genetic changes (BARLOW, 1961). Morphometric characteristics of anchovy in the Adriatic concerning body dimensions have not been sufficiently studied so far. The only existing data are those by PICCINETTI (1971). He stated that the percentage of head length in the total length of anchovy was between 20.42 and 21.02% (s = 0.66 and 0.83 respectively). Those studies comprised only 323 individuals caught near Fano in February and May 1968. Their total lengths ranged between 6.0 and 14.0 cm. The slight difference that can be seen while comparing those results to ours which was probably caused by a larger material: 2834 analysed specimens, and by the wider amplitude of total lengths in specimens we had analysed. The specimens analysed during our investigations ranged between 5.5 and 17.5 cm (mean values) in separate length classes.

Table 6. Body height of anchovy. The mean ($\bar{x}$) is presented with 95% confidence limit (c.l.)

Number of specimens	$\bar{x} \pm c.\ l.$ (cm)	s	$S.\ E.$	BH / L_T (%)
2834	1.38 ± 0.0184	0.4995	0.0094	13.8

Table 7. Body dimensions of anchovy with their statistical values (standard deviation s, mean standard error S.E. and lenght variability coefficient V)

Body dimension	$\bar{x} \pm c.\ l.$ (cm)	s	$S.\ E.$	V
L_A	5.52 ± 0.0568	1.5456	0.0290	28.0
L_C	2.17 ± 0.0190	0.5179	0.0097	23.9
L_O	0.46 ± 0.0041	0.1179	0.0021	25.6
0-0'	0.62 ± 0.0043	0.1158	0.0022	18.7
BH	1.38 ± 0.0018	0.4995	0.0044	36.2

Population structure

Length and age distribution

A total of 4848 anchovy specimens from coastal waters (Kaštela Bay) were examined. Analysis of length compositions of catches related to the sampling month is shown in Figs. 4 - 9 as well as 16 and 17 while the total length and age composition of anchovy is Figs. 10 - 15 and 18.

It is evident from the values presented that the extreme total lengths were in 7.5 cm (9 May 1979) and 17.5 cm (24 April and 14 June 1990) length classes. Mean length values in some samples of catches ranged between 10.1 cm (catch from 9 May 1979) and 15.1 cm (catch from 14 March 1974.). In some samples the fluctuation range in length is relatively small, only 2.5 cm (catch from 21 April 1975), but it is considerable in catches from 24 April and 14 June 1990 amounting to 7.0 cm.

Length distribution curves for anchovy are mainly unimodal and bimodal, approximately symmetrical. A lesser number of catches have polimodal distribution. As it is clearly seen from the schematic drawing, the catches of anchovy with a narrow length amplitude and mainly unimodal distribution were most frequently taken in the period of winter - the beginning of spring. In the following period a

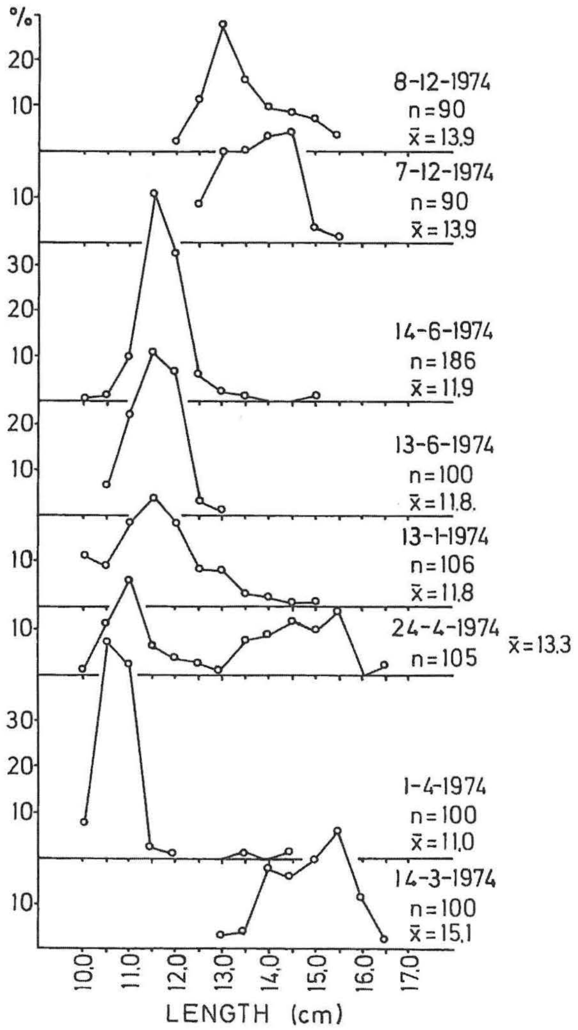

Fig. 4. Monthly total length - frequency distribution of anchovy, Kaštela Bay, 1974

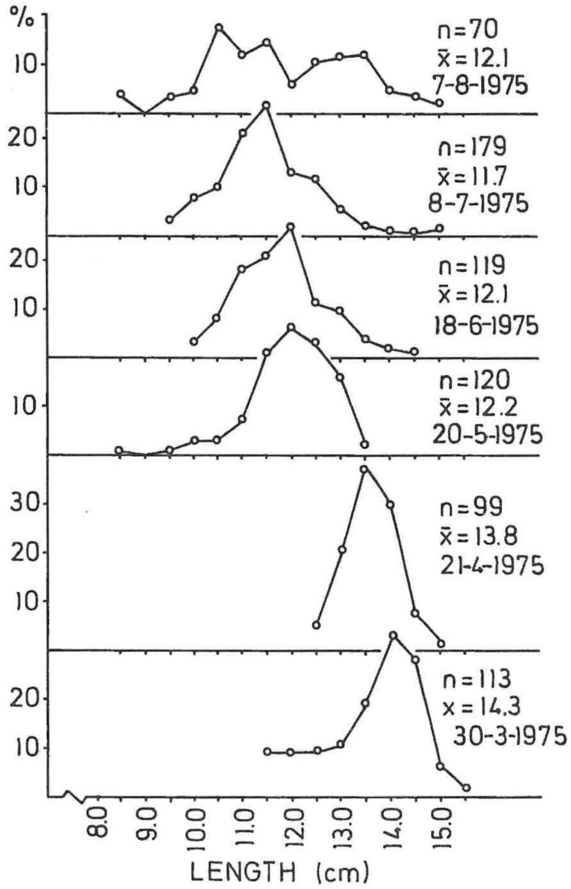

Fig. 5. Monthly total length - frequency distribution of anchovy, Kaštela Bay, 1975

disturbance of these characteristics occured, which is indicated by wider length amplitudes and mostly bimodal and polimodal length distribution of anchovy.

In the whole of the material analysed there are a few dominant modes: fluctuation ranged between 10.0 cm length class (catch from 9 May 1979) and the 15.0 cm one (catches from 14 March 1974). The largest fish in the period of research 1974 - 1979, were recorded mostly by the end of winter and the beginning of spring (Figs. 4 - 9). The exception was the catch from June 1979. After that the length of anchovy specimens started to decrease.

A gradual decrease in length from the beginning of spring to the middle of summer can be seen in the research period from 1974 - 1979. In that time smaller specimens of anchovy are predominant, probably due to the new recruitment. The presence of larger fish is evident at the same time, although being very few. Decrease in the length of anchovy was reflected by decrease of modal length values (Figs. 4 - 9), but also by decreasing mean length values: from 15.1 cm (14 March 1974) to 11.8 cm (13 June 1974) from 14.3 cm (30 March 1975) to 11.7 cm (8 July 1975) and from 13.8 cm (21 April 1976) to 11.4 cm (22 July 1976).

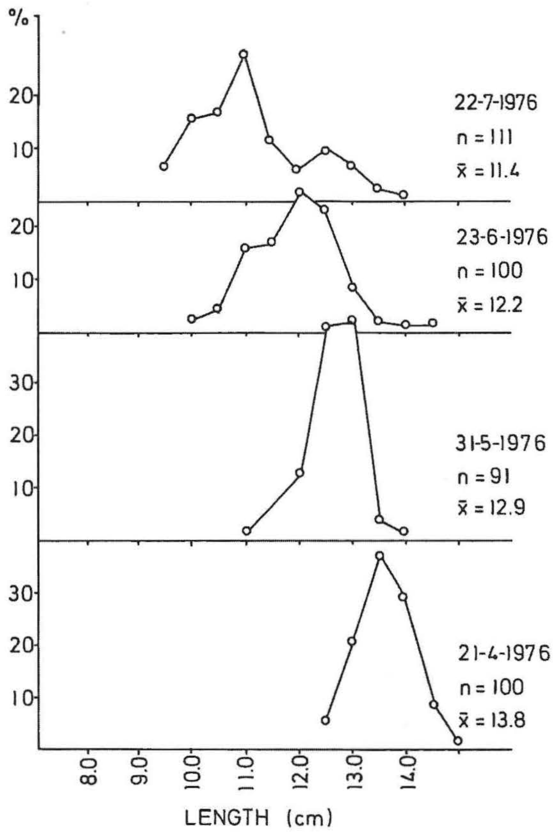

Fig. 6. Monthly total length - frequency distribution of anchovy, Kaštela Bay, 1976

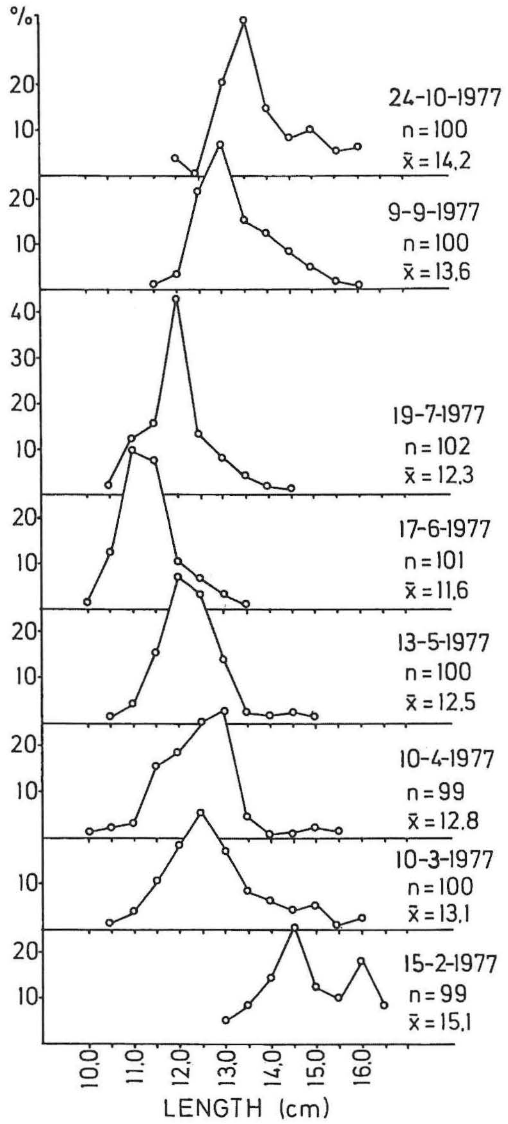

Fig. 7. Monthly total length - frequency distribution of anchovy, Kaštela Bay, 1977

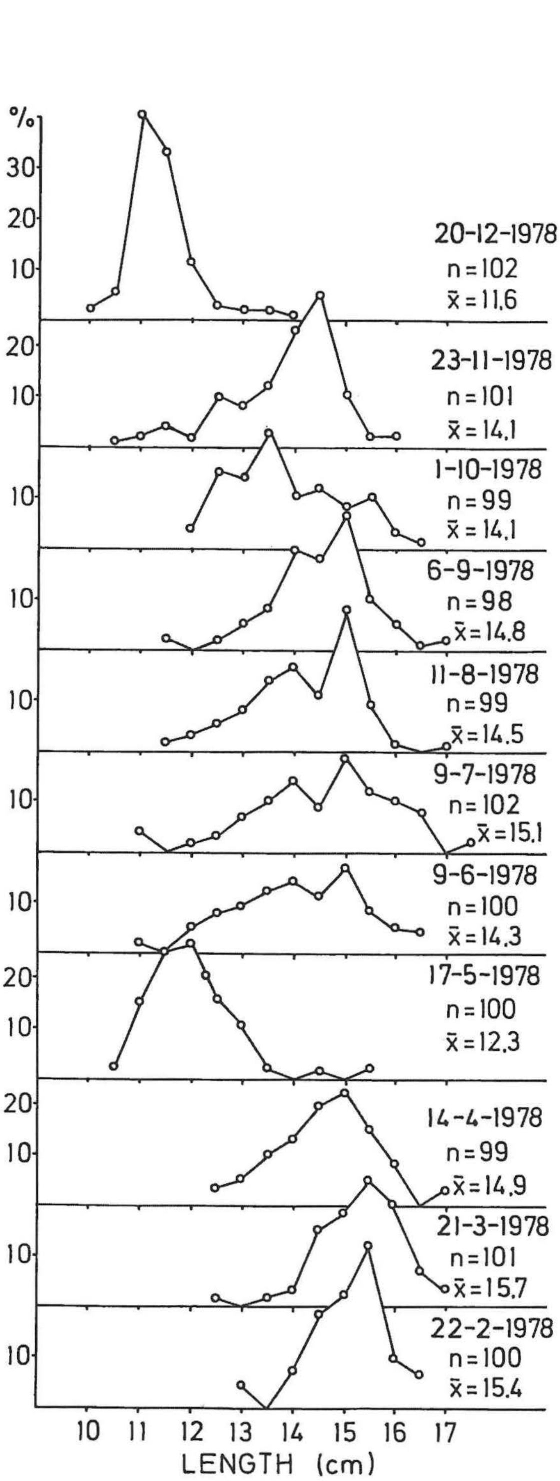

Fig. 8. Monthly total length - frequency distribution of anchovy, Kaštela Bay, 1978

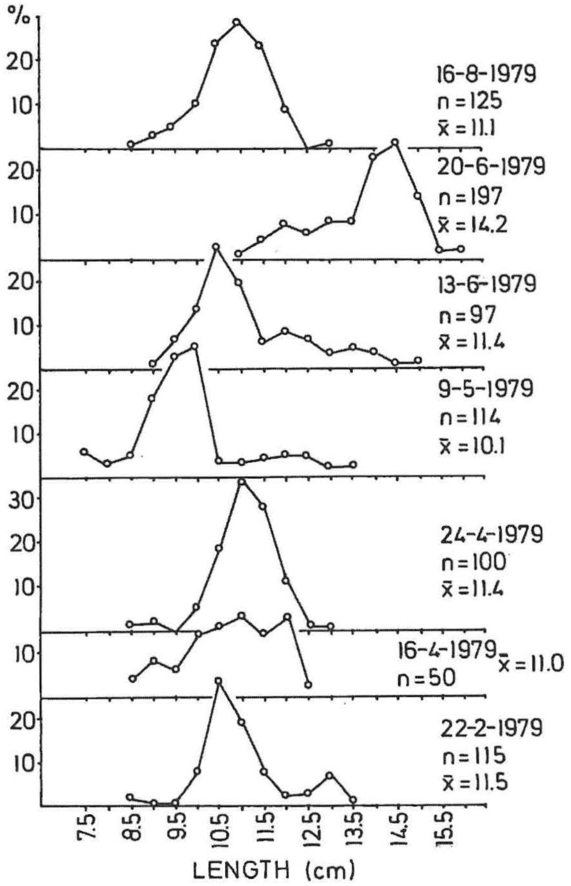

Fig. 9. Total length and age frequency distribution of anchovy, Kaštela Bay, 1979

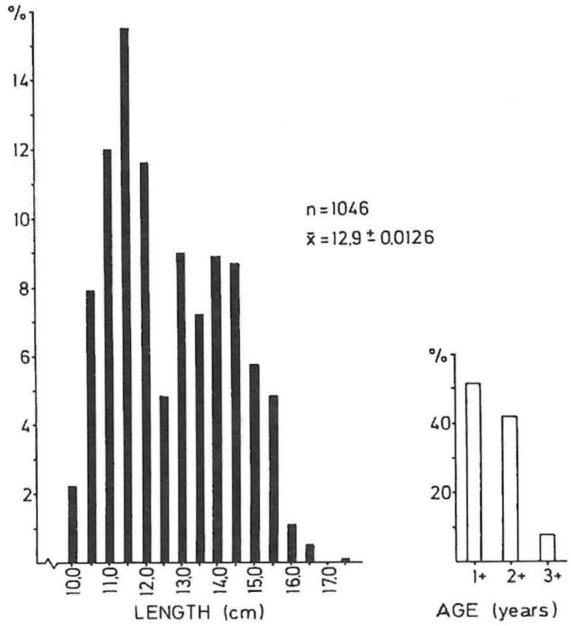

Fig. 10. Total length-frequency and age distribution of anchovy, Kaštela Bay, 1974

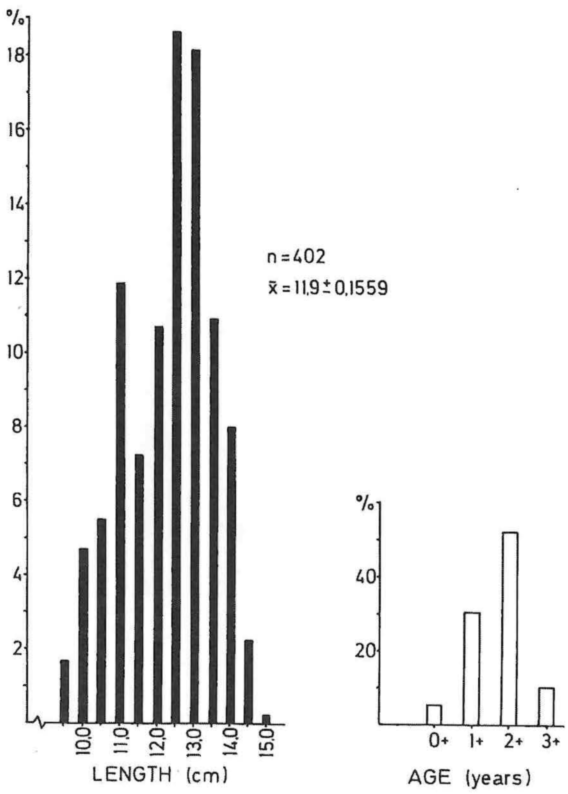

Fig. 11. Total length-frequency and age distribution of anchovy, Kaštela Bay, 1975

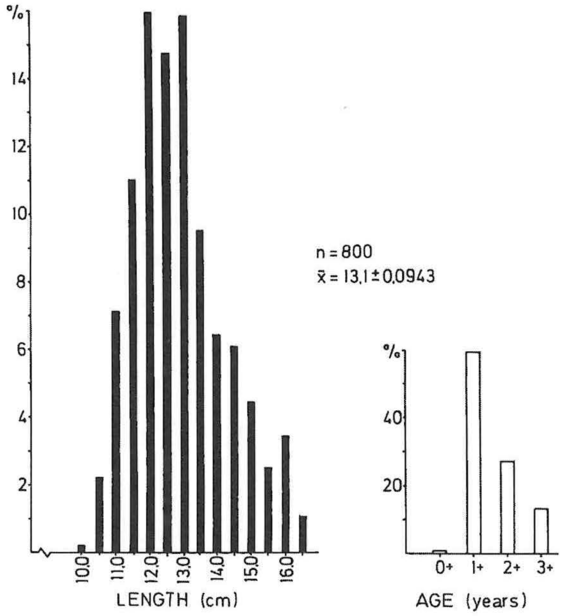

Fig. 13. Total length-frequency and age distribution of anchovy, Kaštela Bay, 1977

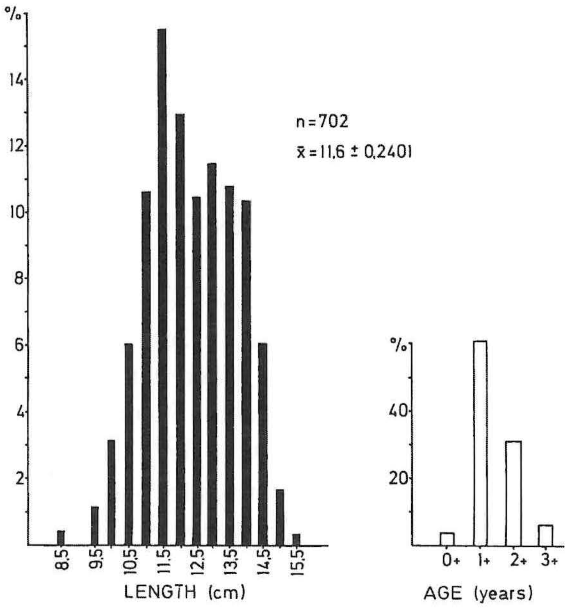

Fig. 12. Total length-frequency and age distribution of anchovy, Kaštela Bay 1976

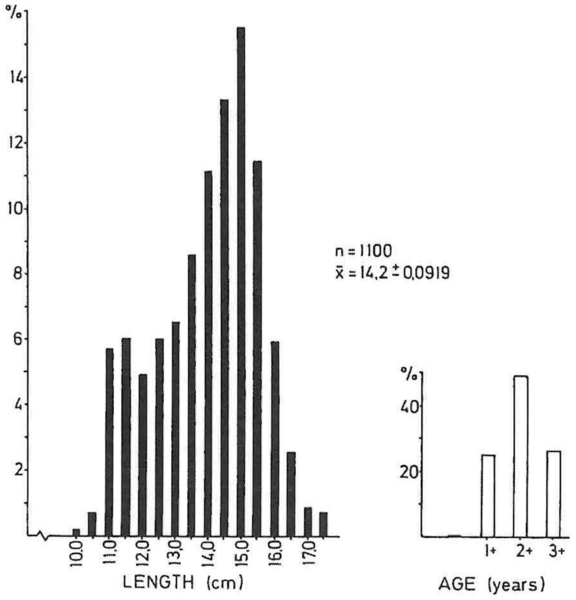

Fig. 14. Total length-frequency and age distribution of anchovy, Kaštela Bay 1978

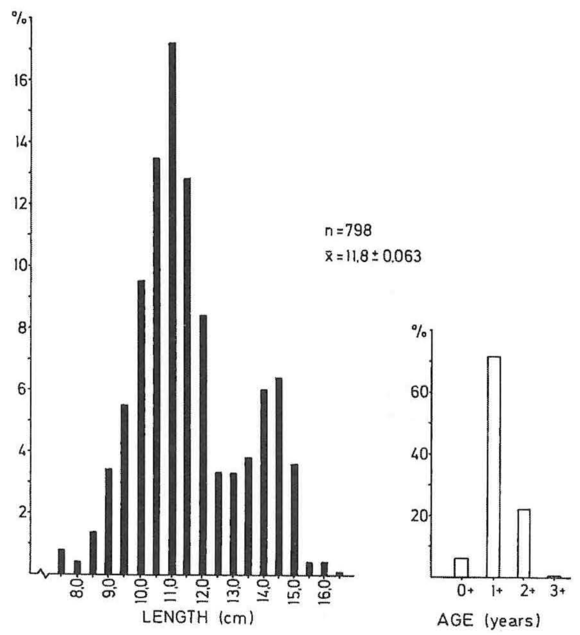

Fig. 15. Total length-frequency and age distribution of anchovy, Kaštela Bay, 1979

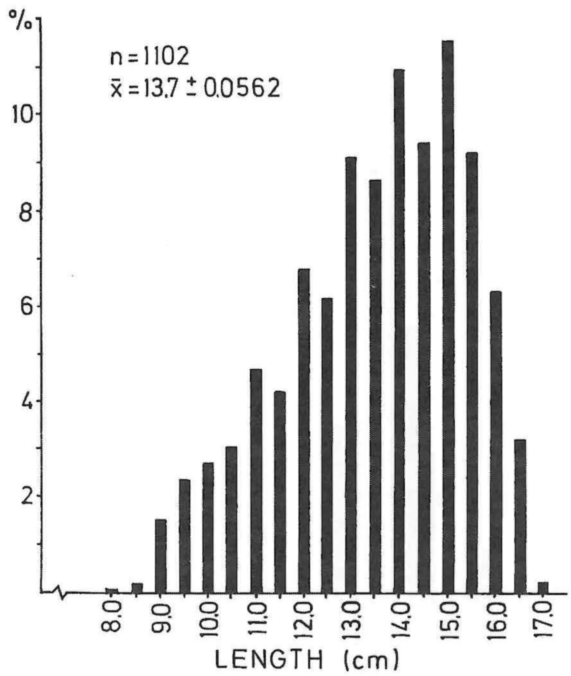

Fig. 16. Total length-frequency and age distribution of anchovy, Kaštela Bay, 1990

Considering the lengths of all anchovy from catches in this area in 1974 globally, it can be seen that 1+ year old anchovy of 11.5 cm length class prevailed in the given year with 51.3 %. 2+ and 3+ groups contributed as follows: 2+ with 41.3% and 3+ with 7.0%. At the same time the 2+ age group contributed fairly well: 37.0 % in the open sea (Vis and Biševo Islands region) and 3+ group an exceptionally good 52.0 % (Fig. 18).

In the period between 1974 and 1978 there was an increase in anchovy length (fishing strategy was unchanged), which is a consequence of the dominant mode increase from 11.5 cm in 1975 to 15.5 cm in 1978, but also of the mean length values increase - from 11.6 ± 0.2401 with the 60.3% prevalence of 1+ age group per year to the mean value of 14.2 ± 0.0919 cm with the prevalence of 2+ age group contributing 48.8% in 1978. At that time the prevalent influence of the strong year class of anchovy was noticed as regards higher percentage in the succesive years of their age. 1+ age group featured prominently in all the years of research except in 1976 and 1977 in which years 2+ group was dominant. The significant contribution of 1+ age class in 1974 (51.3%), and especially in 1975 (60.3%) points to the strong year class of 1973 which brought about the dominant contribution of 1+ age group in the following year.

In the period from May to November 1974 a total of 465 anchovy individuals from the open sea waters were examined, which individuals came from the stations in the south-west part of Vis, Biševo and Svetac Islands, located round three submarine banks (GRUBIŠIĆ and GOSPODNETIĆ, 1955).

Total lenght of anchovy ranged on the whole between 12.8 cm (5 June 1974) to 18.7 cm (17 August 1974), whereas the average total length ranged between 14.9 cm (22 May 1974) and 16.8 cm (17 August 1974) (Fig. 17).

Length distribution curves for anchovy are partly bimodal and one is polimodal. They are mainly asymetrical.

Dominant modal values ranged between 14.0 and 16.5 cm. Considering all the length distributions of anchovy from the samples taken

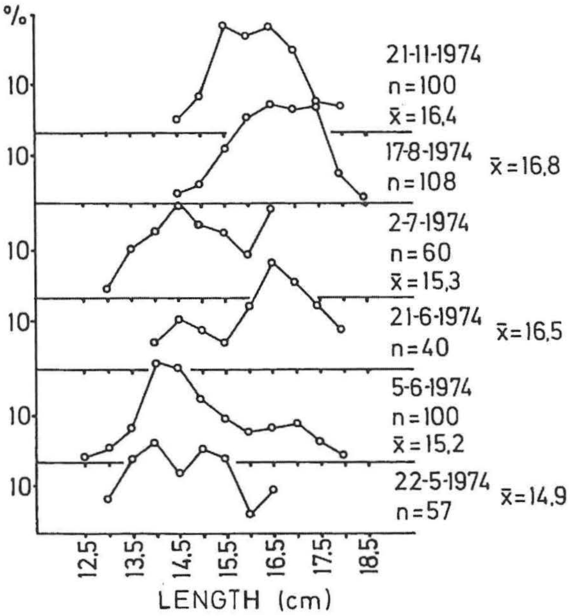

Fig. 17. Monthly total length-frequency distribution of anchovy, Vis - Biševo, 1974

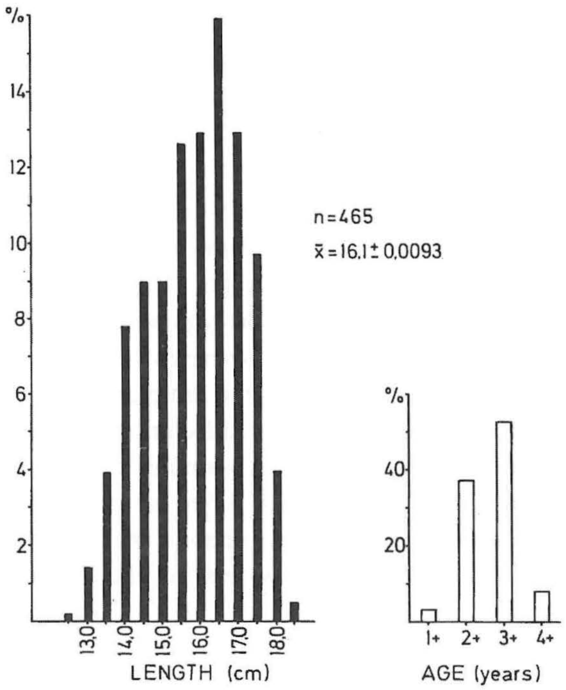

Fig. 18. Total length-frequency and age distribution of anchovy, Vis - Biševo, 1974

in this area in 1974, in the given year of research, the 3 year old anchovy prevailed with 52%, mode being at 16.5 cm, mean length values of 16.1 ± 0.0093 cm and variability V=1.2% (Fig. 18). Contribution of other age classes was as follows: 1+ = 3%, 2+ = 37% and 4+ = 8%.

Data on the composition of commercial anchovy catches indicate the presence of smaller length fish in coastal waters (7.5 - 17.1 cm). The length of fish in the open Adriatic was greater (12.8 - 18.7 cm). Similar was recorded in the western Mediterranean anchovy (BAS and MORALES, 1954) over the period 1949-1951.

Only smaller anchovy (6.0-14.9 cm) were recorded in the rather shallow north - western Adriatic near Fano (PICCINETTI, 1971). Similar to this, small fish (5.2 - 11.0 cm) was recorded in the shallow waters of Israel (BEN - TUVIA, 1953). However, in the Bay of Catania, where depths are greater - from 20 to 105 m, anchovy length was 10.8 - 17.0 cm (DULZETTO, 1938).

Differences in the anchovy size could be indicative of a certain relationship between the fish size and location depth. Considering samples of catches from the trawling season 1954 - 1955 (MUŽINIĆ, 1956), it is evident that larger anchovy are present at depths greater than 70 m. According to the data collected during HVAR Fishery Biological Expedition in 1948 and 1949, which was carried out mainly in the open sea and rarely in the shallow North Adriatic, anchovy length seldom exceeded 15.5 cm at less than 100 m deep, amounting up to 16.5 cm or more at depths greater than 130 m (MUŽINIĆ, 1972).

Direct relationship between anchovy size and depth was established by SUAU (1973) for anchovy from the eastern coast of Spain in June 1968 and 1972.

In the investigated areas the length amplitude was between 7.5 and 18.7 as a whole. It applies to all the analysed lengths of anchovy in this chapter. However, while studying the juvenile anchovy from the Novigrad Sea, the smallest length recorded, was 4.0 cm (SINOVČIĆ, 1992, 1999). Similar length amplitude was recorded along the Bulgarian Coast by STOJANOV (1967), ranging from 3.5 to 17.0 cm in the period 1961 - 1966.

Length change amplitude in the investigation area tended to be very small (2.5 cm), in some samples of catches from coastal waters, but could also be considerable (7.0) indicating greater mixing of the anchovy population from this area with that from the neighbouring one, which was not the case in the samples of catches from the open sea. The difference in lenght change amplitude between samples of catches from this area was smaller (3.5 to 5.5 cm) which points to the more homogeneous anchovy population in the open waters of the Middle Adriatic.

The largest fish was recorded at the end of winter and the beginning of spring, after which a gradual decrease in anchovy length took place. In the same period a narrow amplitude as well as a unimodal length distribution of anchovy were recorded (Figs. 4 - 9). The changes of situation in the subsequent period point to significant migrations of anchovy between this and the neighbouring areas in late spring and during summer.

Similar observations were recorded by PICCINETTI (1971). He recorded a smaller mean length of anchovy in the northern - western Adriatic coastal waters (Fano) in May than in February 1968.

In the research period 1974 - 1979 the influence of strong year class strength of anchovy was evident a few times, which brought about greater contribution in the successive years of their age (see Fig. 38).

The successful appearance of strong year class depends on survival in the so called *critical period*. This term was first used by HJORT (1914) and explained by MAY (1974). For survival in the *critical period*, the time-place distribution of food particles is of primary importance, i.e. the appearance and distribution of phytoplankton and zooplankton in the feeding larvae stage of anchovy. CUSHING (1972) introduced the expression "match - mismatch" based on the existance of natural synchronism between the beginning of reproduction in a species and the enrichment of environment with plankton, which is a source of food for both fry and parental stock. The importance of synchronism is in creating a possibility for parental stock and development stages of anchovy to get adequate food at the right time, thus deciding between successful or unsuccessful spawning and the creation of stronger or weaker next years class. Since anchovy is a species with multiple spawning (DEMIR, 1965; SINOVČIĆ, 1992), each development stage requires adequate density and volume of phytoplankton and zooplankton, which is important not only because of taking different types and sizes of food, but also because of interspecies competition in the interaction of cohorts within the same population (LAMBERT, 1984, 1987; LAMBERT and WARE, 1984). According to AYUSHIN (1963), if an outstandingly strong age class fails to appear within two life cycles, it is necessary to demand protection for parental stock and younger age groups, so as to enlarge the fish stock by accumulation.

Male and female length distribution

Data on male and female distribution of anchovy from samples of catches shown as a whole as well as separately are in Figs. 19-25. Together with mean lengths ($\bar{x}$) for both sexes, standard errors of mean values (*S.E.*) are also noted down along with 95% confidence limits (*c. l.*). To make fluctuations of this factor comparable by area and age, length variability coefficient (*V*) was also plotted.

Total length of anchovy specimens from samples of catches taken in coastal waters (Kaštela Bay) ranged as a whole between 10.0 and 16.9 cm in 1974 and between 7.5 and 16.9 cm in 1979 (Figs. 19 and 20). The range of male length was 6.9 cm (10.0-16.9) in 1974 with a mean of 12.8 ± 0.0883 cm. Together with mean

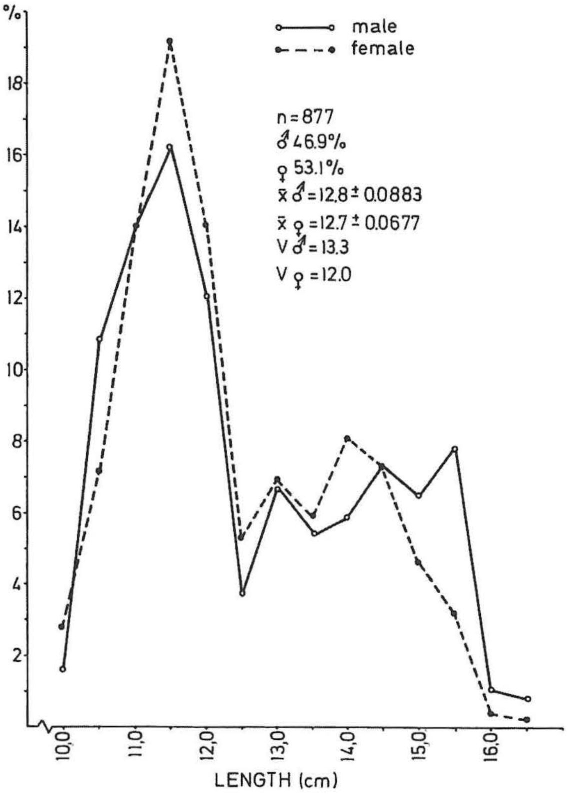

Fig. 19. Total length - frequency distribution of male and female anchovy, Kaštela Bay, 1974

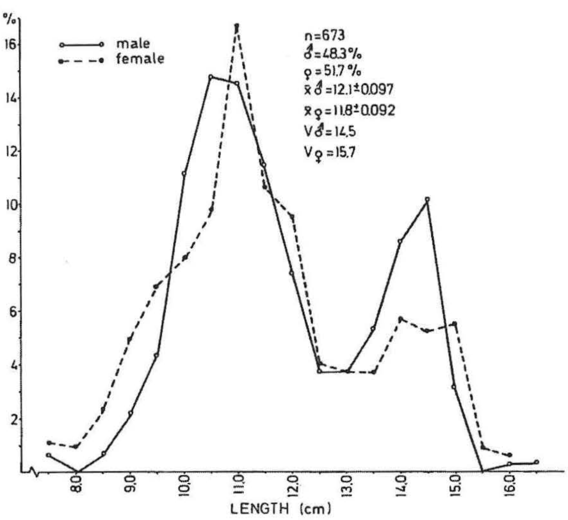

Fig. 20. Total length - frequency distributions of male and female anchovy, Kaštela Bay, 1979

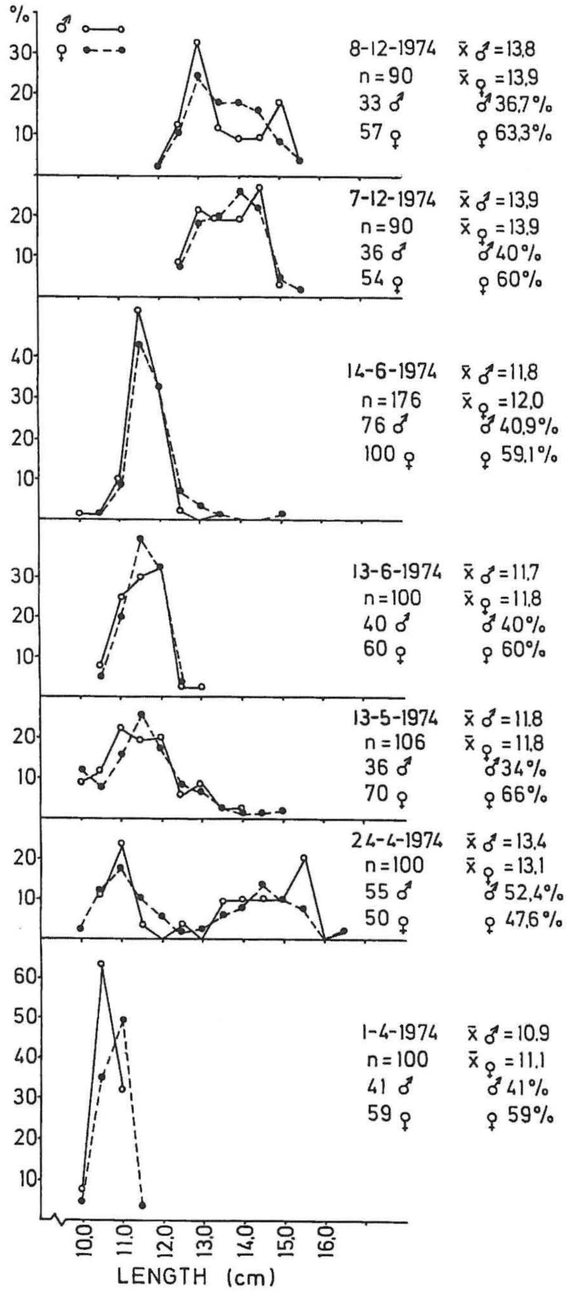

Fig. 21. Total length - frequency distributions of male and female anchovy, Kaštela Bay, April-December

length, the standard error of mean length was also shown. 95% confidence limit was 0.1731. The length range of all males in 1979 was wider compared to that in 1974 and amounted to 9.4 cm (7.5 - 16.9) with smaller total mean length, which was 12.1 ± 0.0974. 95% confidence limit was 0.1909.

The range of body lengths in females was the same as in males in 1974 and amounted to 6.9 cm (10.0 - 16.4 cm), mean length was slightly smaller than that in males reaching 12.7 ± 0.0677 cm in the same research year. 95% confidence limit was 0.1326 cm. The range of female lengths was 8.9 cm (7.5 - 16.4 cm) in 1979, mean length was 11.8 ± 0.0994 cm and 95% confidence limit was 0.1948 cm.

Mean length difference of male and female anchovy from analysed catches made in this area was totally in favour of males in both research years: in 1974 it was 0.1 cm, whereas in 1979 it was 0.3 cm. These differences varied in separate catches alternatively in favour of one sex and the other. A pronounced difference of 0.8 cm in favour of females was noticed in the sample of catch from the middle of June 1979 and a greater difference in favour of males showed in the second half of June in the same year.

Dominant body length mode of anchovy specimens was the same for both sexes in 1974 and had a value of 11.5 cm. In 1979 males were the most abundant in 10.5 cm length group (13.8%) and females in that of 11.0 cm (16.7%). In this region the length - frequency polygon for anchovy of both sexes has an unharmonious distribution with positive asymmetry (Figs. 19 and 20). It can be clearly seen in the schematic drawing that anchovy of smaller body lengths of both sexes prevailed in this area. However, in 1979 males had the greatest body lengths (>15.0), while in 1979 females of such lengths were predominant.

Dominant body length modal values of respective catches were mostly the same for males and females in the research years but they also varied (Figs. 21 and 22) in some samples, males being more abundant in higher length classes and *vice versa*. On the whole the material studied shows similar ranging of modal lengths in both research years so that the modal lengths of males were between 10.0 and 14.5 cm length class in 1974 and between 10.0 and 14.5 cm in 1979 whereas modal length values of females ranged between 11.0 and 14.0 cm in 1974 and between 9.5 and 14.5 cm in 1979.

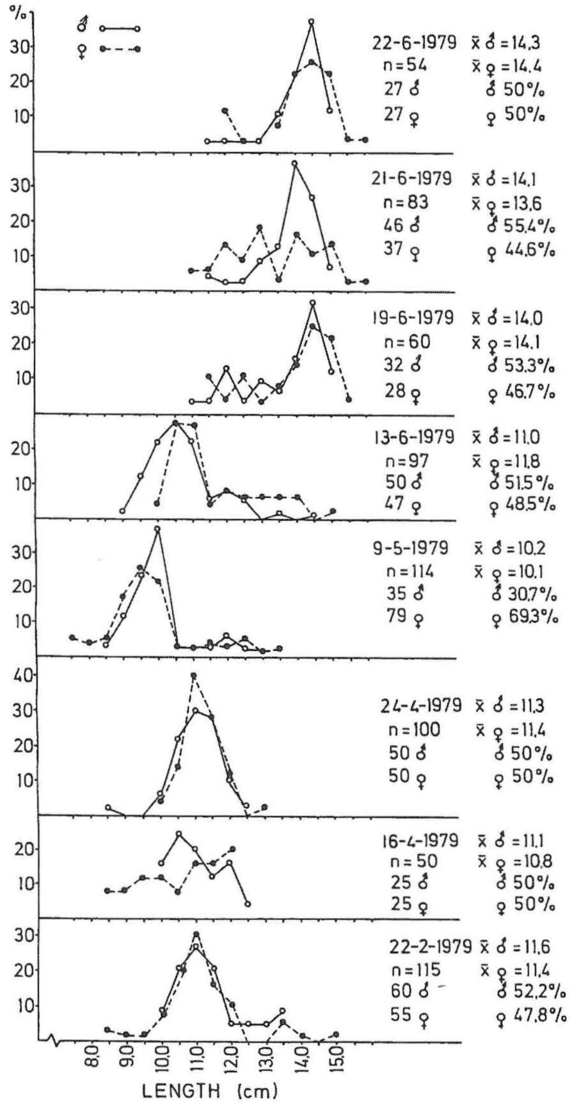

Fig. 22. Monthly total length - frequency distributions of male and female anchovy, Kaštela Bay, February-June 1979

Judging by variability coefficient (*V*), the lenghts of both sexes fluctuated considerably in Kaštela Bay region, so that female length varied slightly less (*V* = 12.0 %) compared to males (*V*= 13.3 %) in 1974. On the contrary, in 1979 female length had greater variability (*V* = 15.7%) than that of males (*V* = 14.5%).

The whole of the studied material from the open sea had bimodal length distribution. The range for males was 5.9 cm (13.0 - 18.9 cm) with mean length of 15.9 ± 0.0751 cm. The

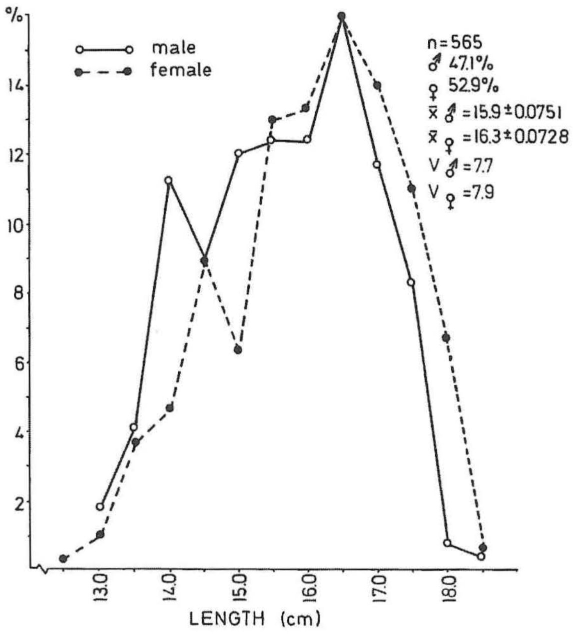

Fig. 23. Total length - frequency distributions of male and female anchovy, Vis - Biševo Islands area, 1974

range for females was 6.4 cm (12.5 - 18.9 cm) with mean length value of 16.3 ± 0.0728 cm (Fig. 23).

In general, there were not any differences in modal lengths of sexes in the samples of anchovy catches from the open sea of the Middle Adriatic in 1974. Namely they contributed most in the 16.5 cm length class, males comprising 16.2% and females 19.2% of it. However, in particular samples of anchovy catches dominant modes fluctuated between 14.0 and 16.5 cm in males and between 13.5 and 17.5 cm in females (Fig. 24). Generally speaking, longer individuals of both sexes prevailed in this area with smaller mean lengths of males (15.9 ± 0.0751) than those of females (16.3 ± 0.0728). Moreover, differences in mean lengths in all the samples of catches were in favour of females . Females were more abundant over 15.0 cm of body length. The most prominent difference - of 0.6 cm, appeared in a sample of catch from mid September 1974, whereas on the whole the difference was 0.4 cm.

Variability coefficient value in males (V = 7.7) and females (V = 7.9) indicates moderate fluctations of this factor in both sexes in the open waters of the Middle Adriatic Sea.

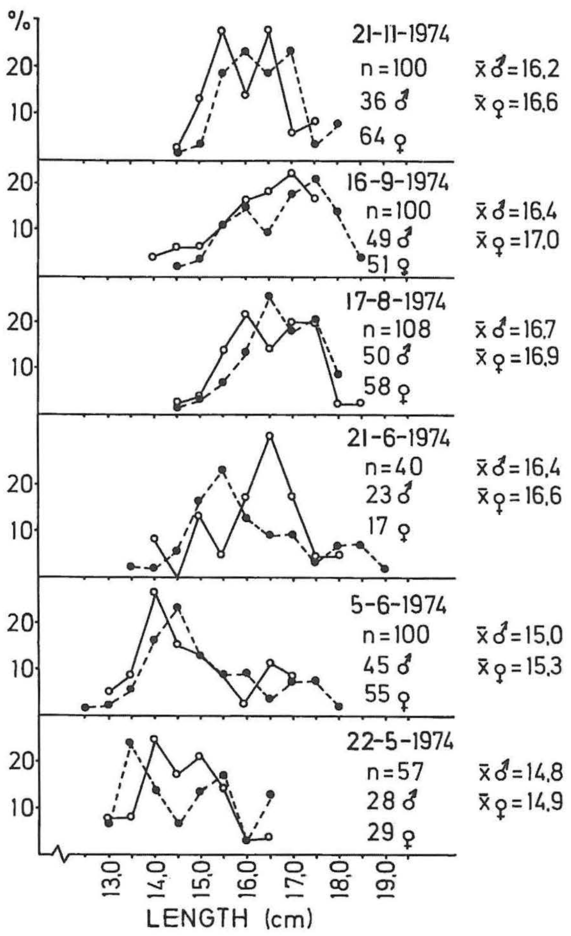

Fig. 24. Total length - frequency distributions of male and female anchovy, Vis and Biševo Islands area, May - November 1974

Furthermore, we particularly analysed the distribution of male and female anchovy in June in three successive years (1979-1981), during period of intensive spawning. A very narrow range of lengths was observed - 3.0 cm in both sexes - from 15.0 to 18.0 for males and from 15.5 to 18.5 for females. Mean lengths were 16.6 ± 0.1119 cm for males and 17.1 ± 0.1072 for females. On the whole the difference between them was 0.4 cm in favour of females. Moreover, in every single catch there was a difference in favour of females and also modal length value was 0.5 cm higher than in males during intensive sexual activity within the three year period (Fig. 25).

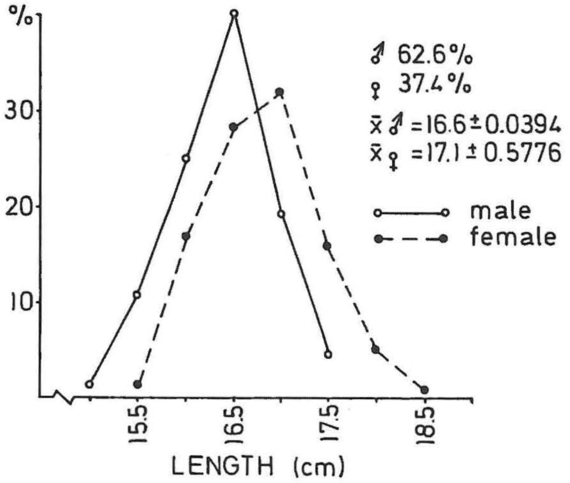

Fig. 25. Length - frequency distribution of male and female anchovy, Vis - Biševo, June 1979, 1980 and 1981

Judging by variability coefficient values, the length of males fluctuated slightly ($V = 5.3$) and that of females even less ($V = 3.1$). This data could indicate a homogeneous anchovy population by length and age in this area during the time of observation.

From the total of 2401 analysed anchovy of both sexes (1181 males, 1220 females), an approximately clear survey of length composition of anchovy population in the coastal waters of the Middle Adriatic (Kaštela Bay) according to sex was obtained.

A wider range of body lengths was recorded in coastal waters and as a whole it was for both sexes between 7.5 and 16.4 cm for females and from 7.5 to 16.9 cm for males. In the open sea the range of body lengths was narrower, it was 5.9 cm, from 13.0 to 18.9 in males, from 12.5 to 18.9 cm in females.

Length composition analysis of this species population, especially according to average and modal lengths, is indicative of some differences by sex in the open sea waters of the Middle Adriatic. Namely, a difference in mean length values between sexes has been recorded in favour of females in all analysed samples of catches. On the whole, the difference was 0.4 cm in favour of females. In this analysis it is necessary to be aware of greater proportion of longer female specimens which most probably influenced the stated differences in mean length values appearing between sexes. Such values are very evident in the time of intensive sexual activity in this area, when modal length values of females were 0.5 centimetres higher than those of males (Fig. 25). However, the schematic drawing of modal length range in separate samples of catches does not show such course. Dominant length mode in females in some samples of anchovy catches was at a greater length than in males (samples from 5 June, 17 August and 6 September 1974), but also at a smaller one (samples from 25 May and 21 June 1974).

Slight differences in mean lenghts, i.e. narrower length range and low variability coefficient, which is very pronounced in the period of very intensive spawning pointed to the fact of a homogeneous anchovy population located in the open sea during their reproduction period.

Higher modal length of females compared to that of males (Fig. 25) is probably the consequence of greater contribution of females to greater body length classes during intensive sexual activity. Namely, the obtained polygon of female length distribution is situated 0.5 cm to the right, towards greater lengths, provided that we observe the polygon of male length distribution in June during reproduction time in the three year period (1979 - 1981) in the stated period of observation. Greater contribution of females than of males in bigger body length classes during maximal reproductive activity could possibly be explained by their inertia during spawning (TEMPLEMAN, 1967). Thus they become more vulnerable to fishing, occurring in higher proportions in catches. It is also possible to assume that females occur in the sea layer closer to the surface in spawning time consequently being more vulnerable to fishing.

The anchovy from samples of catches from the eastern coast of Spain showed very similar difference of the whole examined specimens - 0.4 cm in favour of females - in the period from June 1949 to August 1951 (BAS and

MORALES, 1954). However, in some catches the difference varied considerably more - from 0.2 to 1.5 cm. Male and female anchovy from those eastern Spanish coast catches were mostly of the same modal lengths. It was only in some samples of catches that female modal length was 1.0 cm higher than that in males.

It can be concluded that differences in mean length values between sexes were insignificant. As the differences in some catches were in favour of males and in favour of females in some others, they equalized as a matter of fact. It particularly applies to catches of anchovy from coastal waters, where the difference in length between sexes is almost nonexistent due to migratory movements. No differences in length range were recorded between them either. Differences occur exceptionally in dominant modal values and in mean length values in the period of intensive sexual activity due to greater proportion of females, especially in length classes exceeded 15 cm. It was assumed that differences occured because of different behaviour of sexes in the period of reproductive activity.

Sex ratio

The proportion of sexes in anchovy population was studied on the samples of catches taken by purse seine, with a total of 3854 specimens, in the coastal waters and the open sea waters of the Middle Adriatic from May 1974 to August 1976 inclusive.

The total length of anchovy specimens ranged between 12.5 and 18.5 cm, the dominant mode being at 13.5; 16.5 and 17.5 cm. Some samples of catches from the purse seine contained between 40 and 362 individuals (Table 8).

In the samples of catches from the Middle Adriatic males contributed between 35.3% (October 1974, March 1976) and 60.7% (August 1976) and females between 30.3% (August 1976) and 64.7% (March 1976) (Table 8). The greatest aberration in percentage was recorded in August 1976, reaching 60.7% in males and 39.3% in females. The highest male - female ratio value was 1.5 in favour of males (27 August 1976).

The overall proportion of sexes was almost equal. Out of the total of 3834 individuals there were 1838 males or 47.7% and 2016 females or 52.3% with the sex ratio value of 0.9, which is insignificantly in favour of females.

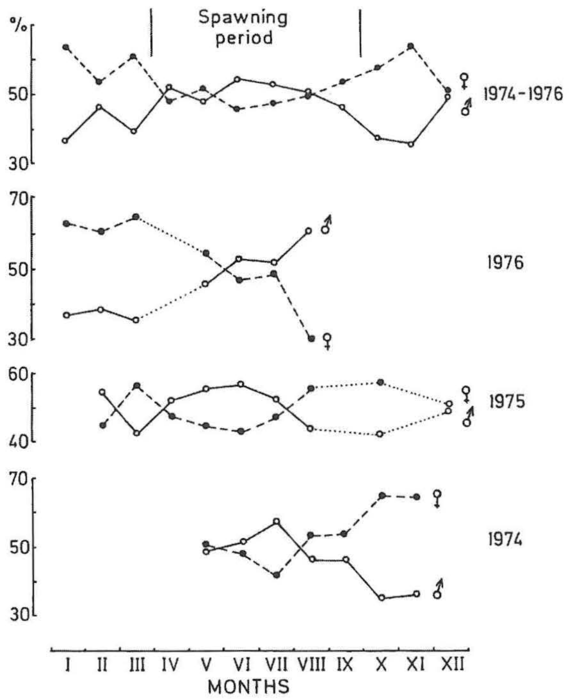

Fig. 26. Monthly frequency distributions of anchovy sexes, Middle Adriatic, 1974 - 1976

In Fig. 26 the annual fluctuation of sex ratio in anchovy is shown according to their physiological state: in the spawning period on one side and in the inactivity period of sexual cycle on the other. By comparing the proportion of sexes in various physiological stages, certain regularities have been noticed. Namely, males were predominant in the spawning period (April - September). Out of the total of 2267 specimens examined in that period, there were 1183 males or 52.2% and 1084 females or 47.8%. Sex ratio value of those specimens was 1.1 in favour of males (Table 8).

Table 8. Monthly distribution of anchovy sex ratio, Middle Adriatic, 1974 - 1976.

Date	Number of individuals	Sex (%)		Ratio
		♂	♀	♂/♀
22 May 1974	57	49.1	50.9	1.0
5 June 1974	100	45.0	55.0	0.8
21 June 1974	40	57.5	42.5	1.4
2 July 1974	60	58.3	41.7	1.4
17 Aug. 1974	108	46.3	53.7	0.9
19 Sept. 1974	362	46.1	53.9	0.9
13 Oct. 1974	292	35.3	64.7	0.9
21 Nov. 1974	100	36.0	64.0	0.5
2 Febr. 1975	190	54.8	45.2	0.6
7 March 1975	210	43.5	56.5	1.2
13 Apr. 1975	135	52.0	48.0	0.8
17 May 1974	110	55.0	45.0	1.1
19 June 1975	138	56.4	43.6	1.2
17 July 1975	157	52.6	47.4	1.3
15 Aug. 1975	201	44.3	55.7	1.1
10 Oct. 1975	100	42.7	57.3	0.8
17 Dec. 1975	100	49.3	50.7	0.7
19 Jan. 1976	137	36.3	63.7	1.0
23 Feb. 1976	215	38.7	61.3	0.8
12 March 1976	243	35.3	64.7	0.6
10 May 1976	278	45.2	54.8	0.5
14 June 1976	149	52.6	47.4	0.8
23 July 1976	193	51.3	48.7	1.1
27 Aug. 1976	179	60.7	39.3	1.5
TOTAL	3854	47.7	52.3	0.9

In the inactivity stage females were predominant namely, out of 1587 specimens of anchovy examined in the research period, 901 or 56.8% were females, whereas 686 specimens or 43.2% were males. Sex ratio value in anchovy examined within the inactivity period of sexual cycle was 0.8 in favour of females.

It can be generally said for the sex ratio of anchovy that females were insignificantly predominant in the population in spite of certain aberrations. It can be concluded on the whole that the proportion of sexes was almost equal. In the spawning period males were predominant, whereas females dominated in the inactivity period of sexual cycle. Similar sex ratio was recorded by other authors. MUŽINIĆ (1956) found a rather equal proportion of sexes in catches achived by trawl in trawling season 1954 - 1955 (52.3% males, 47.3% females and one hermaphrodite).

PADOAN (1963) studied the sex ratio of anchovy from the northern Adriatic in the inactivity period of sexual cycle in 1961. In both years taken together, females dominanted in the inactivity period of sexual cycle with 54.1%, the sex ratio value being 0.8, similar to our surveys from the period when anchovy were in the same physiological condition. VARAGNOLO (1968) found an almost equal proportion of sexes in 1644 anchovy specimens taken in the northern Adriatic within the spawning season, and explained the sporadically ocurring differences by means of anchovy behaviour during spawning season and out of it as well as by fishing conditions.

Reproduction

Sexual cycle

Sexual cycle, namely sexual maturation of the anchovy was analysed by the study of gonads, i.e. their maturity stages on one hand and gonad weight and gonosomatic ratio (GSI) on the other.

Based on standards for determining sex and sexual maturity, we plotted the percentage of unripe gonads (stages I and II), ripening gonads (III and IV) and ripe gonads (V and VI) for each length class of the anchovy individuals in the range of every 0.5 cm was defined. Stage VII was positioned into the third category, with partial spawning having already taken place.

The analysis of data on *gonad state* in 12,752 anchovy individuals from *coastal waters* deals with the succession of monthly fluctuations in gonad state of males and females of anchovy within a ten year period (1975 - 1984). The results have shown (Fig. 27) that less advanced gonad stages - stages I and II-predominated greatly in the samples from the end of winter and the beginning of spring. In April stages I and II were still predominant, although the advanced stages (III and IV) were also recorded. At this stage gonad state was of somewhat more advanced stages in males compared to females. Data on the samples of catches taken in summer months indicate a pronounced prevalence of mature stages (V, VI and VII) in July (50%) and especially in August (60%), when anchovy reached the peak of sexual maturity. It is to be mentioned that stage VI was rarely encountered. Data from November and December as well as from January and February, indicate an inactive period during the sexual cycle of anchovy (Table 9).

Samples of anchovy from the *open sea* were analysed successively from March to December within a five year period, from 1975 - 1979. A total of 4280 anchovy individuals were analysed. As it is shown in the Fig. 28, advanced gonad stages were permanently present from March (40%) to October (3%) with the greatest contribution in July (90%)and August (95%).

The sexual cycle of anchovy was studied on the basis of the fluctuations of gonosomatic ratio (gonosomatic index - GSI) and gonad weight as well.

Data on gonad weight and body weight of anchovy were collected once a month within a five year period (1975 - 1979). A total of 5375 anchovy individuals were examined.

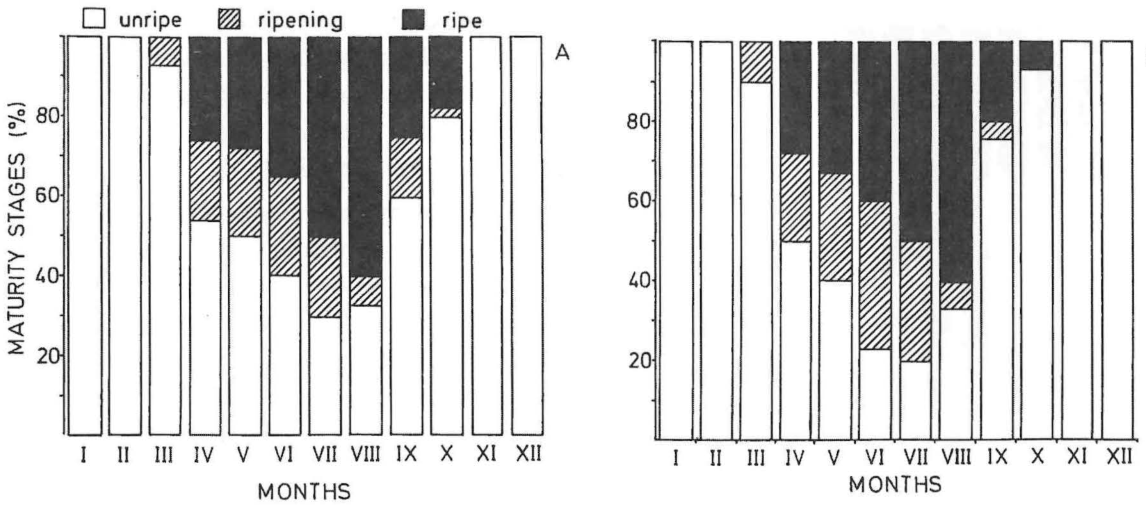

Fig. 27. Monthly fluctuation of mean percentage of gonad maturity stages in anchovy within a year, A-females, B-males, coastal waters, 1975 - 1984

Table 9. Data on average values of gonad weight and gonosomatic index of anchovy during year, Middle Adriatic, 1975 - 1979

Month	Weight of gonads (g)		Gonosomatic index (%)	
	Males	Females	Males	Females
January	0.01	0.01	0.10	0.12
February	0.01	0.05	0.15	0.18
March	0.06	0.13	0.28	0.60
April	0.43	0.51	2.09	2.34
May	0.60	0.83	2.73	3.26
June	0.75	0.90	3.20	3.38
July	0.90	0.96	3.41	3.51
August	0.98	1.15	3.57	3.71
September	0.67	0.74	2.62	2.87
October	0.41	0.45	1.85	2.25
November	0.04	0.10	0.40	0.43
December	0.01	0.02	0.10	0.21

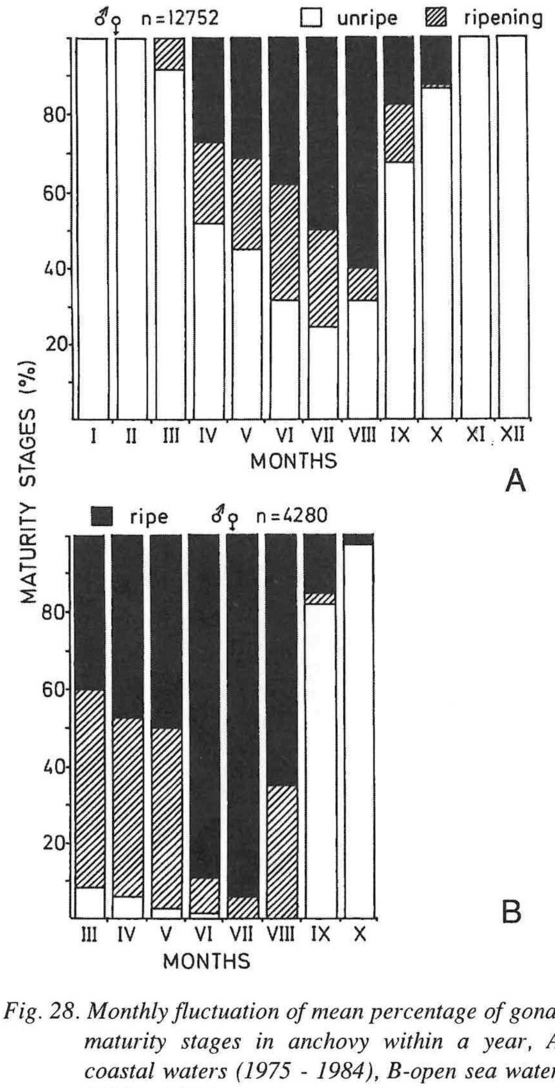

Fig. 28. Monthly fluctuation of mean percentage of gonad maturity stages in anchovy within a year, A-coastal waters (1975 - 1984), B-open sea waters (1975 - 1979)

Data presented on Fig. 29 depicts results of the monthly gonad weight analyses for each sex respectively. The results indicate very low and uniform values of gonad weight and gonosomatic index from January to March. After that period there was a pronounced increase in gonosomatic index and gonad weight lasting until May. After that period a slower increase followed with a peak in August. The greatest ovary weight reached 1.86 g (19 August 1975), and maximum *gonosomatic index* value was 6.53% (19 August 1975), the latter having also been recorded in females. In the period from August to September the gonosomatic index and gonad weight values were decreasing rapidly. Decreasing continued thoughout October. In November and December very low values of both parametres prevailed.

Judging by maximum values of gonad weight and gonosomatic index in the summer months, as well as by the occurence of the most advanced gonad maturity stages at the same time (Figs. 27-29), sexual activity appears to be greatest in that part of the year. This is in accordance with the observations of most researchers who studied anchovy spawning based on the presence of their eggs and larvae in the plankton of the Adriatic Sea (SYRSKY, 1876; GRAEFFE,1888; STEUER ,1910; STIASNY,1910;

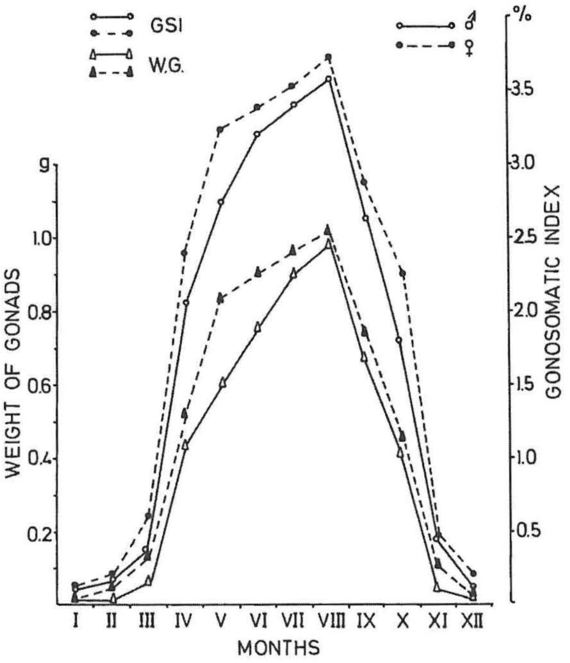

Fig. 29. Monthly fluctuations of gonad weight and gonosomatic index of male and female anchovy, Middle Adriatic, 1975 - 1979

GAMULIN,1940; KARLOVAC, 1963; VARAGNOLO, 1964; ZAVODNIK, 1969; ŠTIRN, 1969,1970; VUČETIĆ, 1971; REGNER, 1972, 1985).

STEUER (1913) observed that anchovy eggs were found from Trieste to Otranto, which is the first data on pelagic fish spawning all over the Adriatic. He particularly pointed to findings in the coastal waters as well as along the east and west coasts of the South Adriatic, this has been supported by later research (GAMULIN and HURE, 1983).

The analysed data of gonad state and gonad weight as well as on the gonosomatic ratio of anchovy individuals from the samples of catches obtained in coastal waters and in the open sea waters during the period of 1975 - 1984 is indicative of anchovy having spawned in those areas from March (open sea) or April (coastal waters) to October (Figs. 27 - 29). As it is noticeable there are differences not only between the times when spawning starts, but also in the time of maximum spawning. Namely, anchovy started spawning earlier in the open sea (in March) and peaked earlier (in July) than in coastal waters (in August).

Anchovy from the samples of catches from both areas ceased spawning in October but the presence of the most advanced gonad maturity stages in October was greater in coastal waters (14%) than in the open sea (3%).

Since considerable concentrations of anchovy eggs (VUČETIĆ, 1971; REGNER, 1972) and of eggs and larvae (KARLOVAC, 1963) were found in the area of Vis and Biševo Islands, it appears that anchovy do spawn there. The presence of anchovy eggs was not great in Kaštela Bay (VUČETIĆ, *ibid.*; REGNER, *ibid.*) and neither were larvae phases (KARLOVAC, 1967).

Anchovy from the open sea samples of catches taken in March and April had a considerably more advanced gonad state than those from coastal water samples of the same months. Since the samples of catches from the open sea consisted of larger fish (Figs. 4 - 25), the difference in gonad state indicated an earlier start of sexual evolution in larger fish, as was formerly stated by SINOVČIĆ (1978). MUŽINIĆ (1956) noted that gonad state in large fish was more advanced at prematuration stage.

An early maturation of larger anchovy was also recorded in other Mediterranean areas where this species occurs (FAGE, 1911; ANDREU and RODRIGUEZ - RODA, 1951; BAS and MORALES, 1954) and in the Atlantic Ocean as well (FURNESTIN, 1943; ANDREU, 1950).

These data are compatible with the observations of difference in size of eggs and larvae at the beginning and at the end of spawning season. As found by REGNER (1972), eggs of anchovy in the Middle Adriatic were smaller in May and July 1968 and 1969 than they were in April. Mean lenghts of larvae were smaller in May, June and July of both years than those in April, as well. NIKOLSKY (1963) ascribed the difference in the size of eggs and larvae to different spawning time in various mature age groups.

The presence of gonad maturity stage referred to as stage VI in all the analyses of gonad maturity stages was rarely recorded, which is in accordance with the observations on this species from Spanish waters (ANDREU, 1950). Namely, this stage is of very short duration and is caused by absorbing water at gonad maturity stage characterized to as stage V. VUČETIĆ (1957) stated that anchovy in the Mljet Lakes hatch between 7 and 9 p. m., hence the probability of coming upon this stage during sampling is much more unlikely than with other stages. Since anchovy are caught by night, during darks which occur at various times of night, there is much less probability to find the specimens of this stage while sampling than other gonad maturity stages in anchovy.

Age and growth

A total of 1510 anchovy individuals were analysed out of which 36.8 % were males and 63.2% were females. Their length ranged between 10.2 and 19.0 cm and their weight was between 7.8 and 30.2 g. April - December 1979 period was comprised.

The following anchovy growth parametres values were calculated :

$L_\infty = 19.4$ cm $\quad W_\infty = 34.8$ g

$K = 0.57 \quad t_0 = -0.5$

All these values were fitted to the von BERTALANFFY equation. Thus the growth equation for the anchovy:

$$l_t = 19.4\ [1 - e^{-0.57\,(t+0.5)}\ ]$$
$$w_t = 34.8\ [1 - e^{-0.57\,(t+0.5)}\ ]^{3.0}$$

by means of which mean length and weight values were plotted for each age class respectively. The date are presented in Figs. 30 and 31.

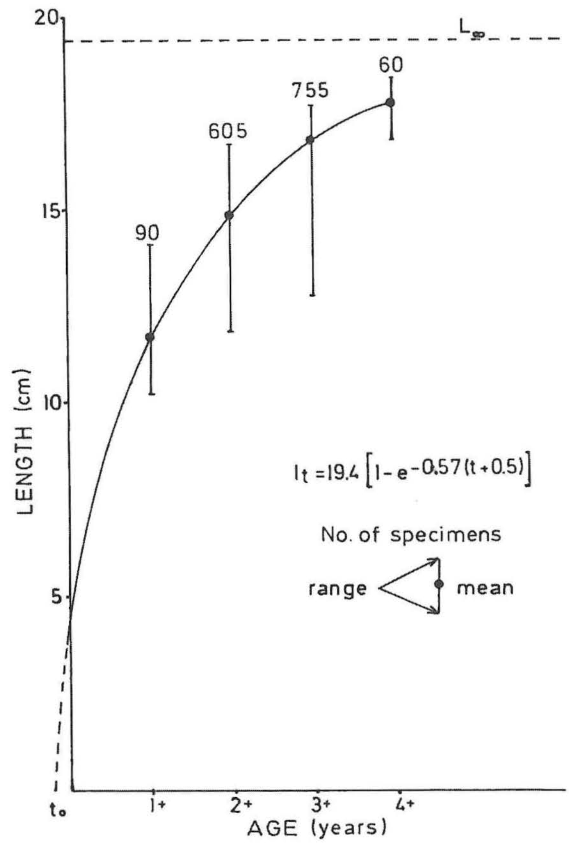

Fig. 30. Length growth curve of anchovy, Middle Adriatic, 1979

Table 10. Length ranges (cm)*, their mean values* ($\bar{x} \pm s$)*, and number of specimens (n) in each age class of anchovy, Middle Adriatic, 1979*

Age class	Males		Females		Both sexes together		Length range (cm)
	n	$\bar{x} \pm s$	*n*	$\bar{x} \pm s$	*n*	$\bar{x} \pm s$	
1+	25	11.8 ± 0.90	65	12.4 ± 0.56	90	11.9 ± 0.98	10.2 – 14.1
2+	310	14.7 ± 0.26	295	15.2 ± 0.27	605	14.8 ± 0.28	11.8 – 16 7
3+	215	16.5 ± 0.32	540	17.0 ± 0.33	755	16.8 ± 0.36	13.8 – 17.7
4+	5	17.3 ± 0.95	55	17.8 ± 0.34	60	17.6 ± 0.97	15.8 – 19.0

Table 11. Weight range (g), their mean values ($\bar{x} \pm s$) and number of specimens (n) in each age class of anchovy, Middle Adriatic, 1979

Age class	Males		Females		Both sexes together		Weight range (g)
	n	$\bar{x} \pm s$	*n*	$\bar{x} \pm s$	*n*	$\bar{x} \pm s$	
1+	25	10.96 ± 2.02	65	12.43 ± 1.50	90	12.08 ± 1.72	6.71 – 17.40
2+	310	22.10 ± 1.56	295	22.10 ± 1.44	605	22.10 ± 1.49	9.58 – 27.90
3+	215	26.20 ± 1.24	540	27.60 ± 1.18	755	27.40 ± 1.21	15.04 – 33.22
4+	5	30.63 ± 1.76	55	31.43 ± 1.34	60	31.03 ± 1.52	29.53 – 34.77

Table 12. Total length distribution of anchovy by age classes, Middle Adriatic, 1979

Length (cm)	Age				Total
	1+	2+	3+	4+	
9.5 – 10.4	3				3
10.5 - 11.4	27	3			30
11.5 - 12.4	40	54			94
12.5 - 13.4	16	117	9		142
13.5 - 14.4	4	125	79		208
14.5 - 15.4		123	127		250
15.5 - 16.4		113	134		247
16.5 - 17.4		70	293	34	397
17.5 - 18.4			113	26	139
Mean length	11.9	14.8	16.8	17.6	15.1
N. of specimens	90	605	755	60	1510

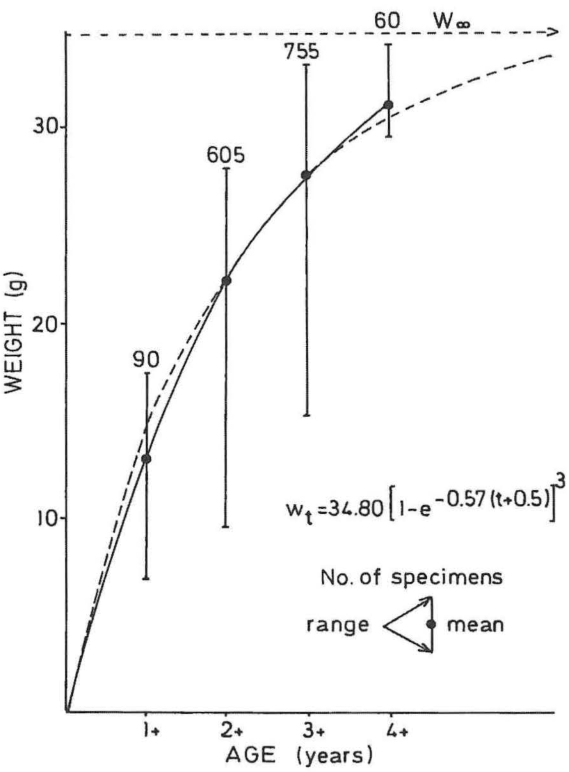

Fig. 31. Weight growth curve of anchovy (full line - actual values, broken line - estimated values), Middle Adriatic, 1979

Presented mean lenghts by age point out that anchovy life span in the Adriatic Sea is five years, from age 0+ to 4+ (Figs.30 and 31, Tables 10-12). There is considerable overlapping of lenghts in anchovy of different ages, particularly in age classes 2+ and 3+. The fastest growth in length and weight in anchovy occurs during the first three years of life. Anchovy specimens attain to asymptotic length in their fourth year of life (3+). However, if we compare the characteristics of growth in anchovy from different areas, from coastal waters (Kaštela Bay) and the open waters of the Adriatic Sea (Vis and Biševo Islands), it is noticeable that neither anchovy of age 4+ were recorded in coastal waters in the time of research, nor anchovy of age 0+ were recorded in the open sea waters (Figs. 10 - 15 and 18).

It was recorded by PADOAN (1963) and SINOVČIĆ (1988) based on the analysis of anchovy age composition of catches from the North and the Middle Adriatic respectively, that the life span of anchovy is five years. The same age range for the Black Sea anchovy was stated by MAIOROVA and CHUGUNOVA (1954) and by PERTIERRA (1987) for anchovy from the western Mediterranean coastal waters. Specimens of anchovy aged 5 were first recorded by STOIANOV (1967) in the samples of catches from the western part of the Black Sea in the spring and summer months of 1963. The author explains their existence by a depopulation of dolphins, the greatest predators of anchovy.

The fact that no anchovy of age 4+ were recorded in coastal waters nor anchovy of 0+ in the open sea waters is explainable by migration of anchovy during their life cycle, probably because of different food demand in the various life stages. Namely, juvenile and one year old anchovy, which feed on phytoplankton at that stage (ZOLEZZI, 1938) satisfy their needs for food and habitation efficiently in coastal waters. That is to say, the quantity and density of phytoplankton are at their maximum in spring and summer in Kaštela Bay (PUCHER - PETKOVIĆ and MARASOVIĆ, 1980) in the period of intensive feeding and spawning of anchovy. Getting older anchovy specimens prefer feeding zooplankton to other organisms, gradually migrating farther away from the coast towards the open sea waters in their life cycle.

The growth parametres of the anchovy had the following values: L_∞ = 19.4 cm; W_∞ = 34.8 g; K= 0.57 yr $^{-1}$; t_0 = -0.5 yr^{-1}. The growth rates of anchovy in the north-western Mediterranean Sea were : L_∞ = 19.10 cm ; K = 0.3491 yr $^{-1}$; t_0 = -1.4499 yr $^{-1}$ according to MORALES-NIN and PERTIERRA (1990). An inverse proportion between an assumed maximum possible length in the life span of anchovy and growth coefficient is in accordance with the general trend for the species with high values of L_∞ to have lower values of K and *vice versa*. It is mathematically logical, since growth coefficient is represented by the curve slope, therefore, the curve slope degree is greater with the greater value of K, so the curve reaches asymptotic length sooner. In other words, with a greater growth rate, the fish reach asymptotic length faster, and final length is smaller. Growth coefficient is considered a genetic feature of a species, whilst L_∞ is phenotypic and can be limited by various environmental factors. Temperature is stated by some authors (GUNTER, 1950) to be the most important limiting factor. They explain that higher temperature stimulate a premature onset of sexual maturity. Growth becomes slower or interrupted and final result is a smaller maximum length.

Fish are very sensitive to temperature changes and respond to a difference of only 0.03°C (BULL, 1952). TAYLOR (1959) found by experiment that an only 1° C change in the mean annual temperature, i. e. from 4°C to 5 °C, reduced L_∞ for 29 cm in the species *Gadus callarias*.

If we compare the greatest anchovy length (19.0 cm) recorded during all our investigation with the estimated theoretically greatest length value that anchovy could research in the life span (19.4 cm), the obtained value points to the fact that 98% of maximum anchovy length was reached. It is an advantage for the species with such a high value of maximum length reached, because the species most probably realized its reproductive potential several times.

Mortality

The estimation of mortality and updating the coefficients of total, natural and fishing mortality are basic problems of dynamics and management of fish populations. The first researchers who dealt with this problem were BARANOV (1918), GULLAND (1965), BEVERTON and HOLT (1956) and RICKER (1975).

The estimation of mortality of fish populations is one of the very delicate analyses in fish biology, where an accurate estimation of age of each specimen is essential. Therefore, we chose to estimate the age of anchovy specimens by reading sagitta otolith.

The values of total mortality (Z), survival rate (S) and annual mortality (A) coefficients are listed in Table 13, from which it is evident that younger specimens have greater values of total and annual mortality coefficients whereas their survival rate is lower. The values of total mortality coefficient were between 0.641 (4+) and 1.550 (0+) with a mean of 1.183. Survival rate showed an increase from the youngest to older anchovy specimens with values ranging from 0.212 (0+) to 0.526 (4+). Coefficient of annual mortality varried between 47 and 79 % (Table 13).

Natural mortality values were obtained by means of the 3.6. and 3.7. equations. The mean

Table 13. Coefficients of total mortality (Z), survival rate (S) and annual mortality (A) for separate age classes of anchovy, Dalmatia, 1974 - 1979

Age class	*Z*	*S*	*A*
0+	1.550	0.212	0.788
1+	1.150	0.317	0.683
2+	0.874	0.417	0.583
3+	0.775	0.461	0.539
4+	0.641	0.526	0.474

value obtained by both equations is $M = 0.65$. We consider the obtained value quite adequate regarding the biological and dynamic characteristics of anchovy population.

Together with the data presented that it is possible to make an approximate estimation of natural mortality (*M*) in some species knowing that species with a high growth coefficient *K* also have high values of natural mortality coefficients. It is mainly characteristic of pelagic species with a short life span (BEVERTON and HOLT, 1956). Our results for anchovy show intermediary values. According to the same authors, an ideal dynamic relationship is estabilished in case of the equal values of natural mortality (*M*) and growth coefficient (*K*).

The proportion between natural mortality (*M*) and growth coefficient (*K*) in different species has different values. BEVERTON and HOLT (*ibid.*) conducted a comparative study of growth and mortality in relation to fishing in several species of clupeideae and engraulidae and found M/K quotient values of between 1 and 2 for almost all the observed species. For the species clupeidae and engraulidae the ratio $M = 1.2\ K$ was found, which value is very close to our result $M= 1.14\ K$.

BEVERTON and HOLT (*ibid.*) consider the essential biological characteristics which define the response of the fish to the exploitation intensity to be found in two quotients: M/K and L_m/L_∞ (L_m = length at first sexual maturity, L_∞ = asymptote length). They found that the estimation of L_m/L_∞ quotient varied from 0.0 to 0.8 for all species, and they have come to the conclusion that a spectrum of species which seem to have very different dynamic characteristics at first sight respond similarly to the intensity of exploitation. For the sardine the value of this quotient was 0.7 (SINOVČIĆ, 1984), whereas for anchovy the value of 0.6 was obtained.

The average value of fishing mortality coefficient is : $F = 0.533$.

The stated value indicates it to be smaller than that of natural mortality. The ideal relationship would be if the coefficients of natural mortality (*M*) and fishing mortality (*F*) were approximately equal, i. e. if it was possible to exploit by fishing the part of the population which would otherwise be removed by natural mortality. These are reasons that make fishery sciences essential in the management of fish stocks. Knowing these parameters it is possible to control the situation in a fish populations and define the limit or the rate of exploitation for a certain fishery, which would provide not only an optimal, but also a permanent yield taking into consideration that the reproductive part of the population must be saved.

The rate of exploitation (*E*) was calculated to be 0.45.

The average values of all the calculated dynamic parametres are as follows:

$$Z = 1.183 \quad M = 0.65 \quad F = 0.533$$
$$S = 0.387 \quad A = 61\% \quad E = 0.45$$

During the research period anchovy of age classes from 0+ to 4+ were established in the catches. The highest mortality rate and the lowest survival were in the youngest individuals. The mean annual mortality was about 61%. A relatively high value of total mortality coeficient ($Z= 1.183$), which is prominent due to a relatively high value of natural mortality ($M= 0.65$), is understandable of this short - lived pelagic species. Fishing mortality coefficient (*F*) has a slightly less influence on total mortality, although the rate of exploitation has an intermediary value ($E= 0.45$).

Migrations

Migratory movements are characterized by horizontal and vertical moving of some population species. Pelagic species are particularly subject to migrations. They are determined genetically, but are also influenced by environmental factors. They include the sense of direction in fish. Migratory movements are mostly determined by: sexual cycle, search for a place to overwinter along with better feeding conditions, but also by changes in the environmental conditions - temperature and salinity (LAGLER *et al.*, 1963).

The movements of anchovy population were considered indirectly, based on the fact that migrations bring about changes in the structure of the population. Data on the composition of catch samples from coastal waters point to the fact that the anchovy from that area with total length ranging between 7.5 and 17.1 cm (Figs. 4 - 16) were smaller than those from the open sea area of the Middle Adriatic with the total length of between 12.8 and 18.7 cm (Figs. 17 and 18). However, in late spring and in summer, an aberration in the more or less usual distribution of anchovy length takes place - the amplitude, modal and mean length values and there are indications which might point to immigration and a prolonged stay of anchovy in coastal waters in that part of the year. It is most probably a migration of anchovy in search for better feeding conditions during breeding season, because it occurs at the beginning of the sexual cycle (Figs. 27-29). That time is characterized by a gradual decline in quantity of mesenteric fat - from their maximum values in January - probably due to redirection of energy spending to the beginning of sexual cycle, although the percentage values of the fattest fish are still very high (SINOVČIĆ, 1978, 1992). Based on this, it can be assumed that anchovy probably find better feeding conditions in that area during spring and the beginning of summer, at the beginning as well as in the spawning season.

Anchovy is a species with a very wide spawning area, which is indicated by the horizontal distribution of their planktonic stages (GAMULIN, 1940; KARLOVAC,1963; VUČETIĆ, 1971; PICCINETTI *et al*, 1979; REGNER, 1982; GAMULIN and HURE, 1983; REGNER *et al.*, 1985). They also spawn near mainland shores (VUČETIĆ, 1971; REGNER, 1972, 1985; SINOVČIĆ, 1978, 1992; GAMULIN and HURE, *ibid.*)

It is well known that in many fish species, the development of gonads during spawning time is connected with the quantity of available food, temperature and salinity values. The time and place of spawning are a result of adaptation in order to secure food for parental stock, planktonic stages and juvenile fish, so that they can grow in as good environmental conditions as possible. According to data collected by DEMIR (1965), in their earlier stages anchovy mainly feed on phytoplankton and prefer warmer, less saline, estuarine areas, while adult anchovy mainly feed on copepods, copepodites and decapod larvae (ZOLEZZI, 1938). The role of food as a limiting factor in the development of clupeid fry is very important, the density of phytoplankton and zooplankton being the most significant in its successful or unsuccessful feeding (LASKER, 1975). It has been experimentally proved that in the controlled environmental conditions, there is a critical density for every species, bellow which values survival is such that the population can not exist (MAY, 1974). The normal density of phytoplankton and zooplankton does not enable optimal survival in natural surroundings, as such fry show signs of malnutrition (HUNTER, 1981). Since anchovy is a spieces with multiple spawning (VARAGNOLO, 1968; SINOVČIĆ, 1992), it seems very important for their fry to be present in the right time, i.e. immediately after parental spawning, in the areas with the optimal density of organisms they take as food (SAXENA and HOUDE, 1972).

Kaštela Bay is the marked anchovy spawning ground (VUČETIĆ, 1971; REGNER, 1972;

SINOVČIĆ, 1978). As the greatest quantities of total phytoplankton in Kaštela Bay area were recorded in spring - summer period (PUCHER - PETKOVIĆ and MARASOVIĆ, 1980) when anchovy spawn, and as there is synchronism between spawning time of anchovy and maximum values of total zooplankton (dry weight), copepods and decapod larvae in Kaštela Bay area (VUČETIĆ, 1975), adult anchovy, their planktonic stages and juvenile fish find very favourable feeding conditions in that area during spring - summer period. Moreover, even abiotic factors are favourable at that time. Namely, juvenile anchovy prefer warmer and less saline sea-water (DEMIR, 1965) and in that period a rise in surface temperature and lesser salinity values were recorded (BULJAN and ZORE - ARMANDA, 1966; VUKADIN, 1991).

The transversal size and age gradual gradient of anchovy in their life span is a consequence of active migration of this species from coastal waters towards open sea waters, the fact being indicated by age composition of anchovy in coastal and open sea areas (Figs. 10-18), as well as in the area of the shallower North Adriatic and deeper Middle and South Adriatic. In coastal waters and in the North Adriatic no anchovy specimens of 4+ age group, as were found in sample catches from the open sea, were recorded or specimens of 0+ age group in the open sea, which indicates a gradual migration of anchovy from coastal waters towards the open sea during their life span. The partial migration of anchovy is most probably related to the type of their diet and overwintering. It mainly occurs within three age groups, 1+, 2+ and 3+, which are more mobile. They have a wider valence for food.

The spring migration of anchovy towards coastal waters has also been observed in the Black Sea (MAIOROVA and CHUGUNOVA, 1954). According to their statements, the Black Sea anchovy start leading an active pelagic life in spring. Then, they appear in the warmer surface sea layers, visit shallower waters, enter estuaries and bays and the period of intensive feeding starts. In autumn and especially in winter, they withdraw into deeper, warmer layers of sea - water, where they overwinter.

Higher temperatures are metabolically more favourable for them. After spring migration they gradually move offshore. In the summer months the Black Sea anchovy do not form densely constituted shoals (MAIOROVA and CHUGUNOVA, *ibid.*).

Fishery

Exploitation

An analysis of anchovy catches was conducted on the basis of the official statistics data presented in the periodical "Morsko ribarstvo" and "Statistical Bulletin" (FAO : 1949 - 1989). In that period substantial changes took place in Croatian fishing for small pelagic fish, which meant an essential improvement in comparison with the earlier period. Such changes happened mostly due to a considerable motorization of the fishing fleet, which enlarged fishing areas. A more extensive use of efficient fishing gear - the purse seine and the pelagic trawl, brought about larger catches and the use of echo sounder made it easier to locate shoals of small pelagic fish. All those factors had a favourable influence on fishing for small pelagic fish. However, due to economical, sociological and some other factors, Croatian fishing statistics do not give an actual picture of the situation and quantities caught although they do indicate certain trends.

The main characteristic of the eastern Adriatic catches is a great proportion of small pelagic fish. During a forty year period, from 1950 to 1989, they contributed between 66 and 85% with an average value of 76 % throughout the period of observation. Sardine is the most important species with the greatest contribution, forming 93.2% of the total small pelagic fish catch in 1989. Other species contributed in 1989 as follows: chub mackerel 2.8%; sprat 2.4%; anchovy 1.1%, and Atlantic mackerel 0.4%. Contributions of separate small pelagic species in the total catch in the Republic of Croatia are shown in Fig. 32. The contribution of sardine in the total catch was the greatest (68.5%), while the contributions of chub mackerel (2.0%), sprat (1.8%), anchovy (0.8%) and mackerel (0.3%) were insignificant.

Another important characteristic of the small pelagic fish catches is their seasonal character. Contributions in the seasonal catches throughout a ten year period are shown in Fig. 33. It is evident from the figure that autumn catches contributed the most (38.23%) and winter the least catches (11.52%). Spring and summer catches were almost equal (23.6 and 26.7% respectively). In the period from 1979 - 1988 midwater trawles were used; they were first used in 1978 in the eastern part of the Adriatic Sea. The seasonal character of the catches was expected to be erased by their use, but unfortunately it was not the case in the whole of the above - mentioned period, although the contribution of the catches taken by was expanded from 21.4% at the beginning of the period studied to 24.6% at the end of it. The catch in 1989 is somewhat different due to a larger catch in the first trimester (Fig. 34), i. e. in the winter, and a little lower catch in the last trimester, i. e. in the autumn, while in the spring/summer period the catches are approximately equal to the means of the whole ten year period catches. Possible causes can probably be found in the more favourable weather conditions in autumn and in the probable redirection of purse seines to fishing for other, more profitable and demanded species, especially tuna.

Anchovy catches have fluctuated from year to year. In the 1947/1989 period the catch ratio was 1: 18.23 from the lowest 397 tons catch in 1947 to the highest 7238 ton catch in 1967. If observed as a whole throughout the entire period, the total annual anchovy catch showed a slight upward tendency of increase (b = 27.34 tons), with a considerable variability (70%). However, it can be seen from Fig. 35 that the period observed is dividable into two periods by catch:

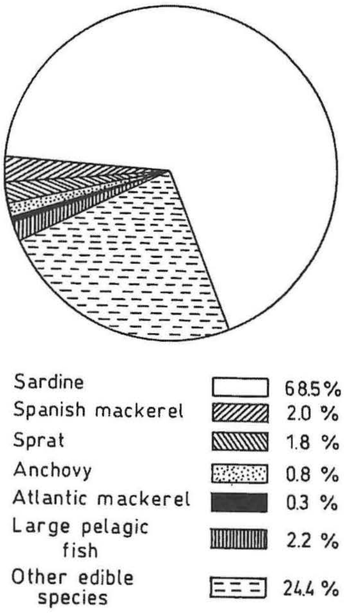

Fig. 32. Contributions of separate small pelagic species in total catches of the Republic of Croatia, 1950 - 1989

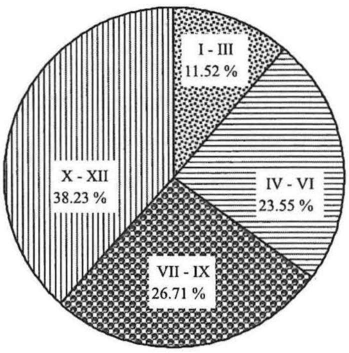

Fig. 33. Seasonal percentage portion of small pelagics total catches, eastern Adriatic, 1979 - 1988

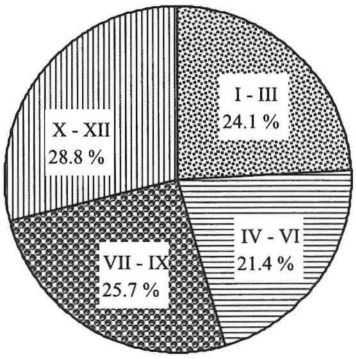

Fig. 34. Seasonal percentage portion of small pelagics total catches, eastern Adriatic, 1989

- the period of a gradual increase of anchovy catch - from 1954 to 1967 (b = 242.288 t) that took place after very low and similar anchovy catches in the period from 1947 to 1953. The increase in quantities of anchovy catches was especially pronounced in the period from 1961 to 1967, in which year maximum catch ever was recorded - 7 238 tons. The variability coefficient for that period was 89.36%.
- the period of a pronounced decline in anchovy catches (b = -134.201 t), from 1968 inclusive to 1988, in which period there was only one marked maximum, in 1985, with the catch of 3559 tons and after that there has been a pronounced decline so far. In the stated period one more period of stagnant catch can be distinguished from 1972 to 1982, when anchovy catches ranged with minor aberrations on the level of the average catch value in the entire studied period, the value of 2579.09 tons of anchovy (s= 1541.67). In that period the variability coefficient was 49.03%.

If we compare the eastern Adriatic catches to those realised on the western coast, it is noticeable that the quantities of the Italian catches obtained in the western part of the Adriatic are much greater and that the fluctuations of total Adriatic catches are determined by catches realised in its western part. Studying the fluctuations of anchovy catches in Croatia in comparison with the Italian catches (Fig. 35), alternation tendencies can be observed in the first period of studying - from 1966 to 1975. After 1975 there was mainly a coincidence trend in the eastern and western Adriatic coast anchovy catches, namely greater catches on one side of the Adriatic were followed by greater catches on the other.

This can probably be related to the fluctuations in the anchovy population size in certain years, but also to economical reasons - greater or lesser market demand for this species. It is especially true of recent years, when the demand for this species has increased considerably on our and the Italian market as well.

Deducing by total monthly quantities of anchovy catches and their average values, anchovy were caught throughout the whole year, from January to December in the period of observation (1980 - 1986) in the eastern part of the Adriatic Sea (Fig. 36).

However, what characterizes monthly catches on the whole is the inconsistency of catch - the prevalence of great catches in the summer months: July, August and especially in

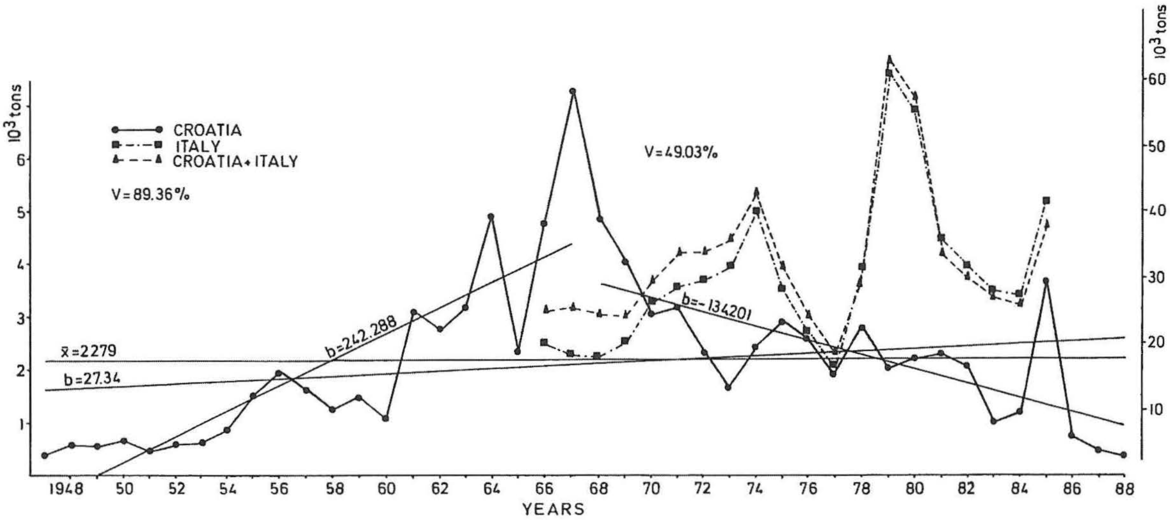

Fig. 35. Fluctuations of total annual anchovy catches of Croatia (1947 - 1988), Italy (1966 - 1985) and both catches together (1966 - 1985). The scale on the left refers to the Croatian catches, and the one on the right to the Italian as well as Italian+Croatian catches (solid line:Croatian catches, dotted broken line: Italian catches, broken line: Croatian total catches together with Italian total catches)

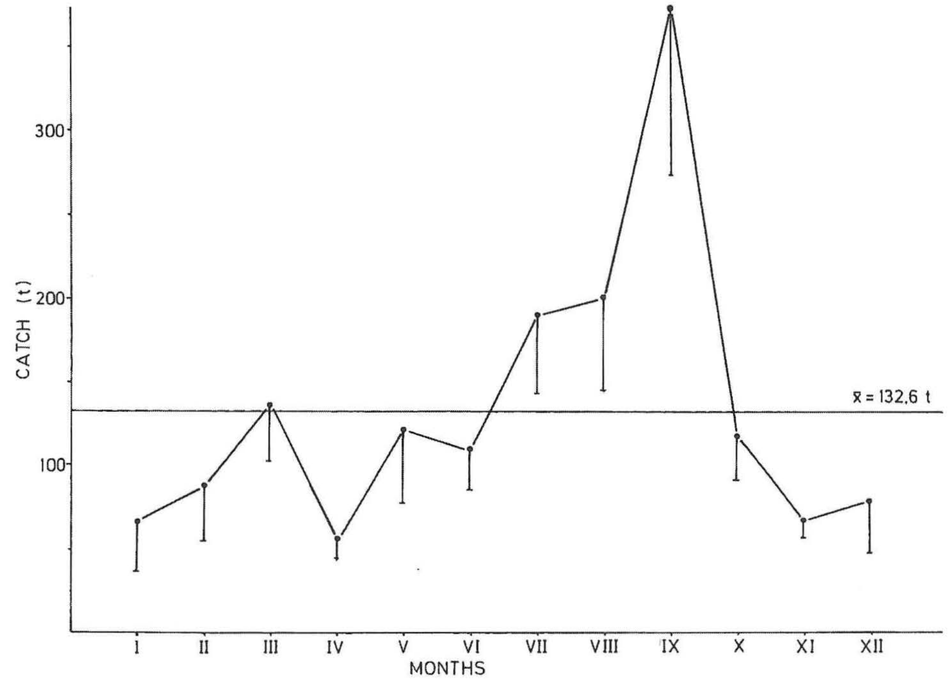

Fig. 36. Monthly fluctuations of mean Croatian anchovy catches ($\bar{x}$, s), 1980 - 1986

September (Fig. 36), when 48.0% of the total catch in the studied period was achieved. In that time all the values of catches were considerably above the average values of realized catches, which amounted to 132. 59 tons, while in the other part of the year the realized anchovy catches were smaller than the average value, except for March catches with the value of 137.47 t, the value being close to the mean value of all catches.

The lowest anchovy catch (371.7 tons) was realized in April. The average catch in the same month of the studied period was 53.1 tons. The highest catch of 2162 tons, was achieved in September (Fig. 36) with the mean value of realized catches amounting to 373.14 tons . It is important to mention that the means of achieved catches fluctuated more when their values were smaller.

Similar changes in the monthly distribution of anchovy catches were noticeable before (MUŽINIĆ, 1982).

Besides, the analysis of anchovy catches per fishing day in different seasons in the open sea area of Dugi otok also points to the fact that the highest quantities were achieved in the summer period 1979 - 1983. The catch per unit of effort (kg day^{-1}) showed the following quantities, according to SINOVČIĆ *et al.* (1991): in winter 952 tons, in spring 665 tons, in summer 1476 tons and in autumn 1245 tons.

The maximum quantities of summer catches are most probably due to favourable conditions for fishing by artificial light. It is also the time of intensive spawning of anchovy and hence the time of their greater aggregability. The fat quantity in the visceral cavity is low, although an increase was recorded during September, which is connected with the intensive feeding of this species after spawning. The structure of anchovy population is changed at that time due to migration. A longitudinal flow of the surface layer of sea water with relatively slow speed is evident in the middle Adriatic: 5 cm sec^{-1} in August and September (ZORE - ARMANDA, 1966), together with a greater presence of copepods (VUČETIĆ, 1975). Zooplankton occurs nearer the surface in that time of the year, especially in September (HURE, 1964), when the highest catches in all the periods studied were obtained (Fig. 36).

Estimation of population size and optimum sustainable yield

The anchovy population size estimation was made by the *VPA* (*V*irtual *P*opulation *A*nalysis) quantitative - analytical method which has been used for the last thirtyfive years (GULLAND, 1965; MURPHY, 1966; POPE, 1972; JONES, 1981).

The *VPA* method has been widely used in fishery research lately, the more so because it takes into consideration biological characteristics of species, age structure, characteristics of growth, length - weight relationship, mortality, etc. This method is based on the conceptual approach that the number of individuals of every age group being taken from a stock by fishing faithfully presents the real number of individuals of the same age classes in the sea. To estimate the size of anchovy population in the investigated areas almost all the previously calculated parameters of anchovy population were used. It was concluded that the stated area was inhabited by a homogeneous anchovy population (SINOVČIĆ, 1982). Population composition by length, age and sex was estimated, growth parameters, length-weight relationship coefficient, weight-at-age, total catch and the number of individuals per kilogramme were calculated as well as total, natural and fishing mortality coefficients, together with the rate of exploitation.

The *VPA* method is particularly sensitive to the accuracy in estimating the mean length of every age group and less as regards the mortality coefficient and catches (PELLETIER, 1990). However, in order to avoid estimating errors as much as possible, the coefficient of natural mortality was plotted by two methods, the TAYLOR'S (1959) and the RICHTER - EFANOV'S (1976). To assess the coefficient of natural mortality (*M*) the average value obtained by means of the stated methods was used.

It was assumed that mortality coefficients (*M, Z* and *F*) and the exploitation rate of the population (*E*) did not change very much from 1974 - 1979, in which period the estimation of the abundance of anchovy was obtained.

Errors can often be made due to the seasonal migrations of the species but were reduced to a minimum by studying the age composition of anchovy throughout the whole year. It was stated in the chapter on migrations that they have a seasonal character in anchovy and occur in a wider region of Dalmatia, from coastal waters towards the open sea and *vice versa*, in different seasons, whilst in coastal waters the composition changes in a definite cycle. Therefore, taken as a whole, the effect of migrations is lost and errors are reduced to a minimum if the composition of the population is observed through successive months. The data on anchovy catches from Kaštela Bay and Dalmatia region have been taken from the ex-Yugoslav statistical bulletins dealing with cattle - breading and fishery for the period of 1974 - 1980.

The length means of anchovy individuals used for this purpose ranged between 8.0 and 18.5 cm and weight means were from 3.30 to 31.03 g. The average number of individuals fluctuated between 58 and 68 individuals per kilogramme in Kaštela Bay area, whilst in the area of Dalmatia it was between 32 and 70 individuals per kilogramme. Total annual catches ranged between 17 and 69 tons in Kaštela Bay and between 339 and 1169 tons per year in the area of Dalmatia region, and in the Republic of Croatia from 1650 to 2342 tons (Table 14).

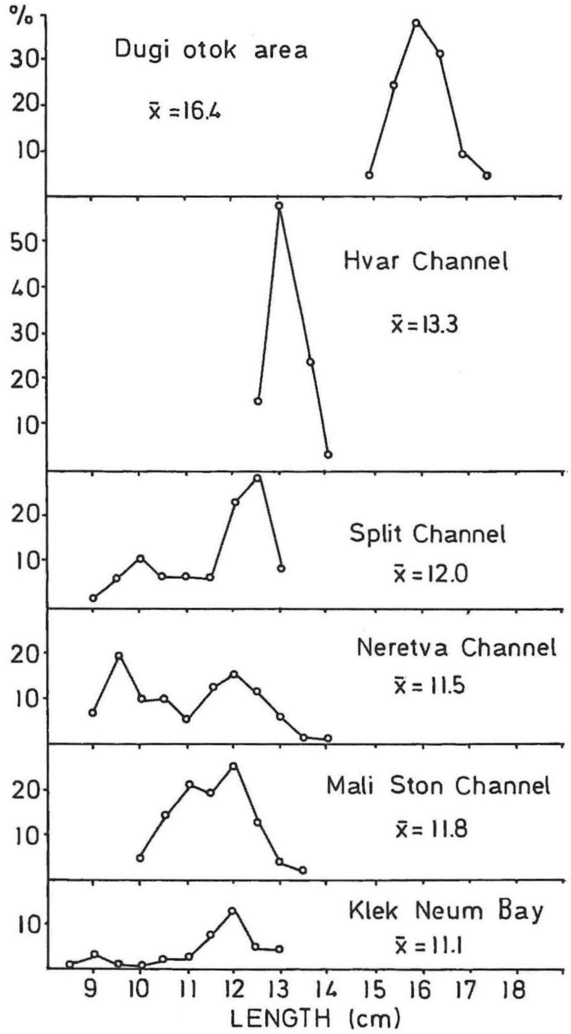

Fig. 37. Length frequency distribution of anchovy, Dalmatia region, 1976 - 1988

The length distribution frequencies from different parts of Dalmatia region and the range of their means are illustrated in the Figs. 4 -18 and 37. According to the values presented on Table 14, Figs. 10 - 15, 38 and 40 it is noticeable that individuals belonging groups to age 1+ and 2+ form the greatest part of the catches.

The calculated growth parameters of anchovy are as follows: $L_\infty = 19.4$, $W_\infty = 34.80$, $K = 0.57$, $t_0 = -0.5$, whilst population dynamics parameters of total (Z) natural (M) and fishing (F) mortalities as well as the exploitation rate (E) of the oldest age class (4+) of anchovy are as follows:

$$Z = 0.64;\ M = 0.5;\ F = 0.15;\ E = 0.23$$

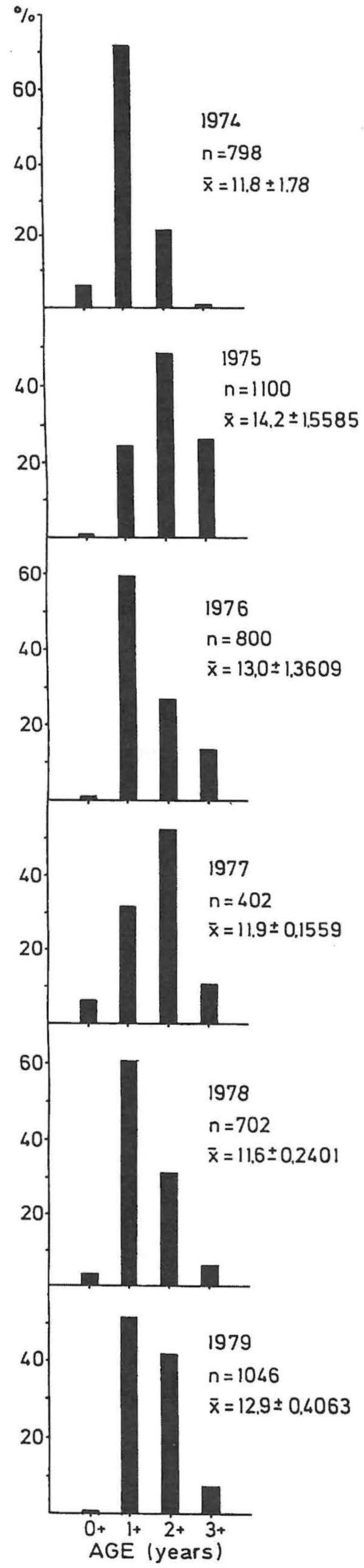

Fig. 38. Age composition of anchovy, Kaštela Bay, 1974 - 1979

Table 14. Quantities of anchovy catches taken in Kaštela Bay, Dalmatian and Croatian fishing grounds, together with the percentages of their age classe portion in Dalmatia (within parentheses) and in Kaštela Bay catches (no parentheses), 1974 - 1979

Year	Yield (t)			Portion of anchovy age classes (%)								
	Kaštela Bay	Dalmatia	Croatia	0 +		1 +		2 +		3 +		4+
1974	17	1169	2076	0.3	(0.4)	51.3	(51.0)	41.3	(41.1)	7.0	(7.0)	(0.5)
1975	17	1115	2342	3.1	(3.5)	60.3	(60.0)	30.8	(30.2)	5.8	(4.3)	(2.0)
1976	31	1045	2079	6.0	(4.0)	31.3	(29.7)	52.2	(51.3)	10.4	(10.3)	(4.7)
1977	69	990	1550	0.3	(0.3)	59.8	(57.3)	27.0	(27.0)	13.0	(13.0)	(2.4)
1978	36	786	2114	0.2	(0.2)	24.6	(22.4)	48.8	(46.4)	26.4	(26.4)	(4.6)
1979	55	339	1650	6.1	(15.2)	71.4	(70.4)	21.7	(20.5)	0.8	(3.2)	(10.7)

The value of length - weight relationship in Kaštela Bay is :

$$W = 0.0040\, L^{3.1195}$$

and in the region of Dalmatia:

$$W = 0.0123\, L^{3.0}$$

On the basis of the values presented, following the procedure proposed by JONES (1981), the quantity of exploited anchovy population in Kaštela Bay and in Dalmatia for the period 1974 - 1979 was estimated.

In order to establish the possible increase of anchovy catch without the critical state of overfishing, the maximum sustainable yield (*MSY*) for this population in Kaštela Bay and in Dalmatia region was plotted.

The size of anchovy population in the stated areas fluctuated between 44 t (1975) and 264 t (1977) in Kaštela Bay and between 631 (1979) and 2,982 t (1976) in the area of Dalmatia (Tables 15 and 16). The estimated maximum sustainable yield ranged between 21 t (1975) and 125 t (1977) for Kaštela Bay area and between 298 t (1979) and 1411 t (1976) for the Dalmatia fishing grounds. Since the total annual quantities of anchovy caught in the same period in Kaštela Bay ranged between 17 t (1974 and 1975) and 69 t (1977) and between 339 t (1979) and 1169 t (1974) in Dalmatia region, it can be concluded that catch values for some years were above the established *MSY* value, slightly higher in 1979 for both areas (Fig. 39), more in Dalmatia in 1975 (19%), which is the consequence of inadequate stock management of this species in the stated areas. In the other years of the period the management of this species was not optimal either, which is indicated by the difference between the realized catches and the calculated levels of maximum sustainable catch. It is possible to state that the exploitation of anchovy population was rational only in 1977 in Dalmatia region (Fig. 39) pro-

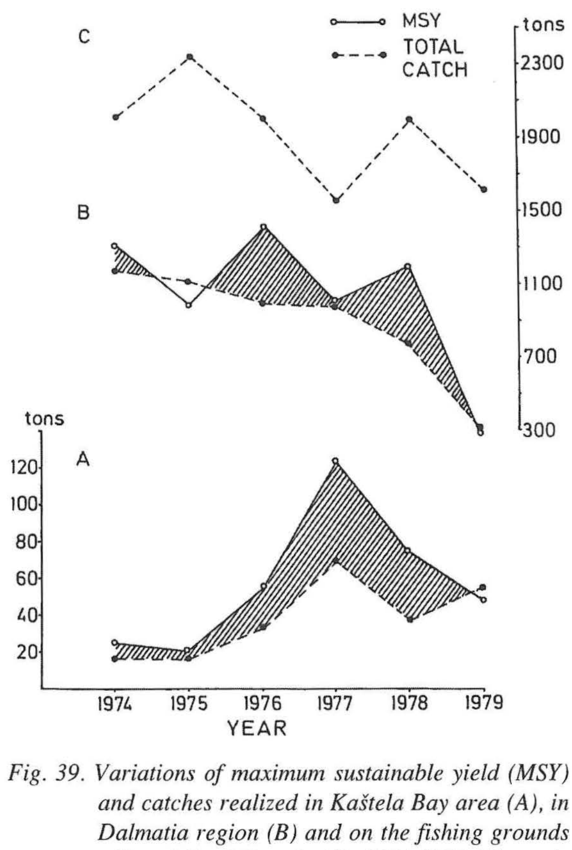

Fig. 39. Variations of maximum sustainable yield (MSY) and catches realized in Kaštela Bay area (A), in Dalmatia region (B) and on the fishing grounds of Republic of Croatia (C), 1974-1979. The scale on the left shows the values for Kaštela Bay, on the right there are values for Dalmatia and the Croatia fishing grounds

Table 15. Anchovy population size, yield estimation according Virtual Population Analysis VPA(t) and maximum sustainable yield (MSY), Kaštela Bay, 1974 - 1979

Age class			0+	1+	2+	3+	*VPA*(t)	*MSY*(t)	Possible increase (%)
Population size by age class	1974	N(10^3)	1883	1548	811	300	51.057	24.207	+29.8
		t	6.214	18.700	17.923	8.220			
	1975	N(10^3)	1765	1420	632	248	43.741	20.698	+17.9
		t	5.825	17.154	13.967	6.795			
	1976	N(10^3)	3900	3088	2014	813	116.958	55.342	+44.7
		t	12.870	37.303	44.509	22.276			
	1977	N(10^3)	8687	7168	3931	2260	264.055	124.95	+44.8
		t	28.667	86.589	86.875	61.924			
	1978	N(10^3)	4332	3604	2658	1569	159.565	75.506	+52.3
		t	14.296	43.563	58.742	42.991			
	1979	N(10^3)	5304	4135	1022	130	94.712	44.712	-14.5
		t	18.564	50.000	22.586	3.362			
Yield (t)	1974		3	506	407	69			
	1975		31	594	303	57			
	1976		108	563	939	187			
	1977		12	2393	1080	520			
	1978		3	337	668	361			
	1979		228	2670	811	30			

vided that statistical data describe the situation accurately. While doing the calculations, the criterion was adopted according to GULLAND (1970), who considered that 40% can be taken from the population without any risk of unbalance or endangering for the anchovy parental stock .

Considering the represented data of fluctuations of maximum sustainable yield and catches realized in Kaštela Bay and Dalmatia, it is evident that the fluctuations of catches realized in Kaštela Bay were to the great extent a reflexion of the size of anchovy population, that is, maximum sustainable yield (*MSY*), although the population could have been exploited 20 (1975) to 52% (1978) more than it had been (Tables 15 and 16, Fig. 39), while the catch in Dalmatia was kept at approximately the same level of

Table 16. Anchovy population size, yield estimation according Virtual Population Analysis VPA(t) and maximum sustainable yield (MSY), Kaštela Bay, 1974 - 1979

Age class			0+	1+	2+	3+	4+	*VPA*(t)	*MSY*(t)	Possible increase (%)
Population size by age class	1974	N(10^3)	99819	81993	43111	16036		2747.483	1300.108	+10.1
		t	329.402	990.475	952.753	439.386	35.467			
	1975	N(10^3)	80395	64102	25785	7760	4356	1973.375	933.801	-19.3
		t	281.383	774.352	569.849	212.624	135.167			
	1976	N(10^3)	90259	72696	47026	17121	9608	2982.261	1411.206	+25.9
		t	297.855	878.168	1039.275	469.115	297.848			
	1977	N(10^3)	65365	65984	29629	12771	4957	2171.332	1027.474	+3.6
		t	215.704	797.086	654.801	349.925	153.816			
	1978	N(10^3)	57890	58638	40861	18808	7074	2537.260	1200.631	+34.5
		t	191.037	708.347	903.028	515.339	219.506			
	1979	N(10^3)	31935	25137	6822	1591	670	630.577	298.389	-12.0
		t	111.773	303.655	150.766	43.593	20.790			
Yield (t)	1974		210	26829	21620	3682	263			
	1975		1753	30051	45126	2154	1002			
	1976		1881	13966	24124	4844	2210			
	1977		143	27229	12830	6178	1140			
	1978		71	7923	16412	9338	1627			
	1979		881	11933	83475	50542				

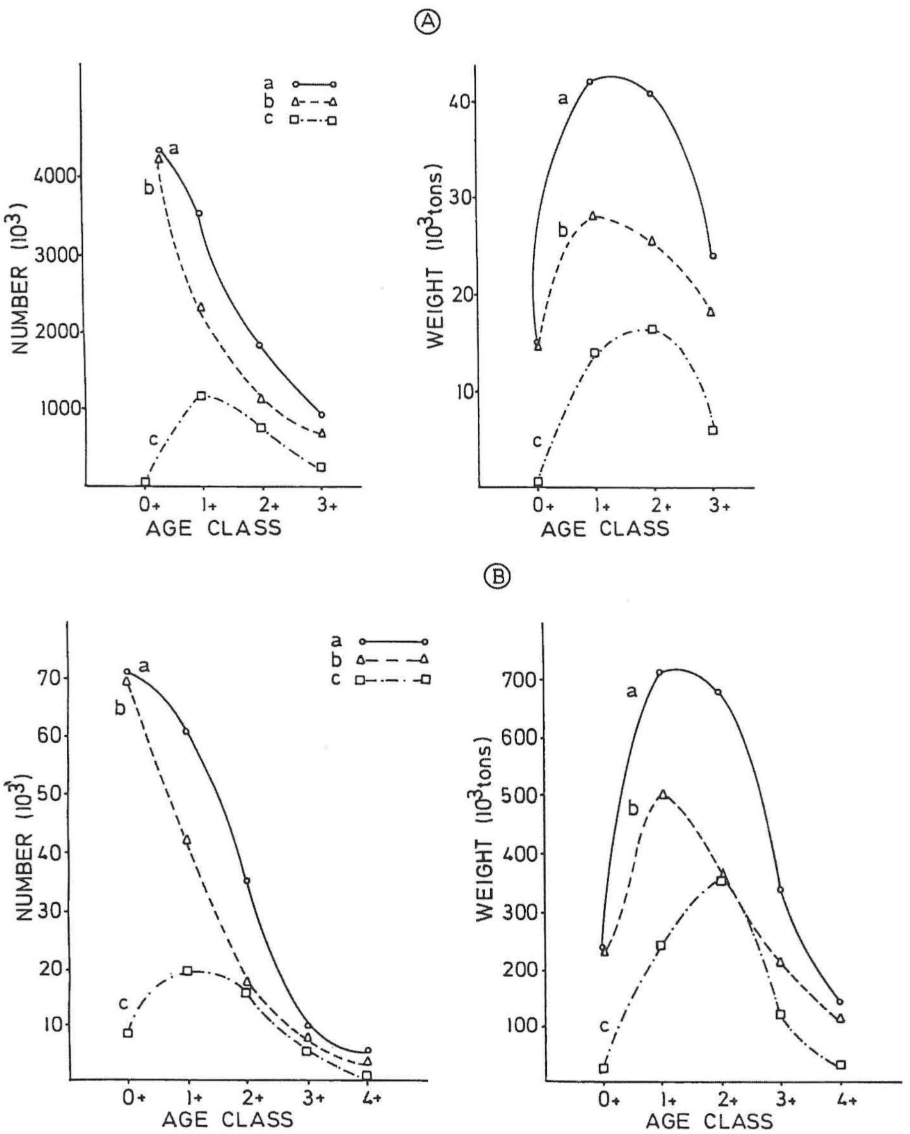

Fig. 40. Assessed quantities (a), retained individuals (b) and yield per recruit (c) of the age classes of anchovy population in Kaštela Bay (A) and Dalmatia region (B), 1974 - 1979

1000 t, which value reflects the average catch in the observed period and was not the result of the anchovy biomass fluctuation. In 1975 the catch was even 20% greater than was the value of *MSY*. In spite of catches greater than maximum sustainable yield, the negative consequences of such a negative catch in 1975 were not felt. On the contrary, there was an increase in both the size of the population and the maximum sustainable yield in Dalmatia. According to the results of the studies by REGNER (1985), who stated excessively high abundance of anchovy eggs in the open sea in 1975 and 1976, it is assumable that such abundance of anchovy eggs together with favourable ecological factors brought about a strong annual class registered during our research. Such a strong annual class reflected favourably on an increase in anchovy biomass and consequently on the calculated greater values of maximum sustainable yield in Dalmatia in 1976 and in Kaštela Bay in the subsequent year. Thus, the positive influence of the newly recruited fish prevented the negative influence of biologically greater catches than allowed by the value of *MSY* in 1975.

It would be very harmful for anchovy population if insufficient recruitment and inadequate management of the species overlapped, in the sense of taking greater catches than allowed by the exploitation rate *MSY*. Fortunately, it was not the case in Dalmatia in 1975.

The abundance values of anchovy population by separate age classes during research period in the area of Kaštela Bay and Dalmatia presented in weight quantities and numerically, the yield per recruit, and retained individuals are shown in Fig. 40.

It is evident from the figure that juvenile anchovy were the most numerous in both areas, while in older specimens a tendency of decrease in numerousness is noticeable. The yield per recruit in age group 1+ is the greatest if observed numerically in both areas, while the weight yield in age group 2+ was the greatest in both research areas during the research period. Numerically observed, the greatest number of specimens belonging to group 0+ remained in the sea and observed by weight, those from group 1+.

At the end, the catches fluctuation trend of the realized catches in the fishing grounds of the Republic of Croatia was compared to the fluctuation trend of the estimated anchovy stock size in Dalmatia. Except for 1975, in all the other research years (1974 - 1979) the ranging of catch quantities realized in the fishing grounds of Croatia was found to be followed by fluctuations of quantities of anchovy population in Dalmatia and *vice versa*. Such a trend seems to have reflected the population size of this species and wider. The population size of anchovy seems to be more the reflexion of natural fluctuations in biomass due to interactions between this population and the environment than it is due to the human activities.

In all these observations it is necessary to take into consideration biological features of this small and short lived fish species. Such species can suffer a greater intensity of exploitation and they renew faster than those with a longer life span. The majority of the anchovy population consisted of younger age classes and population size was mainly dependant on the intensity of recruitment. Accordingly, natural fluctuations were far more important concerning the size population of this species than the man activities as a predator of fish stock in the research period 1974 - 1979.

According to BEVERTON and HOLT (1957) there is a dynamic balance in a fish population when natural mortality coefficient (*M*) and growth coefficient (*K*) are approximately equal and also when natural mortality (*M*) and fishing mortality (*F*) coefficients are equal. In the case of anchovy exploitation in Dalmatia, similar relationships were observed between the stated dynamics coefficients. In this way the part of the population which would run the risk of loss due to natural mortality is taken from it by fishing.

Moreover, from the length values of the analysed individuals it is evident that the maximum possible growth in length was realized within 98%. The survival rate of anchovy was not high (39%) but since they reached their first sexual maturity early, i. e. at the end of the first year of life (SINOVČIĆ, 1998, 1992, 1999) and their life span is five years (from 0+ to 4+), they realized their reproductive potential throughout at least three years.The high amount of anchovy fecundity was established (SINOVČIĆ, 1992).

Several authors have assessed the quantity of anchovy so far, mainly using the method of assessment by eggs and larvae. ŠTIRN (1969) calculated the quantity of 250,000 tons for 1965, using the mean egg number in regard to the overall area of the North Adriatic. VUČETIĆ (1976) used the egg density method in the same anchovy spawning area as ŠTIRN (*ibid.*), and obtained the value of 190, 000 tons of anchovy for the whole Adriatic. KARLOVAC *et al.*, (1974) estimated the quantity of anchovy and sardine populations at 600,000 tons on the basis of primary production, efficiency of trophic levels and egg and larvae density. KAČIĆ *et al.* (1980) estimated the quantities of anchovy and sardine in the eastern part of the Adriatic at 122,572 tons by echo sounding. PICCINETTI *et al.* (1979) assessed the anchovy population in the Adriatic to be 297,000 tons by means of the overall number of eggs and larvae during 1976. In the course of the assessment they failed to take into consideration the mortality of eggs between spawning and eclosion. Using population dynamics method CINGOLANI *et al.* (1998) assessed that the quantity of anchovy biomass varied between 35,000 and 370,000 tons in the Adriatic Sea during the period 1975-1996. During that period, strong fluctuation of anchovy biomass was evident.

Since the methods of assessment are different as well as the research period and area, it is not possible to compare them to our research.

In neither of the quoted assessments the relationship between the assessed population size and maximum sustainable yield (*MSY*) of the anchovy was presented.

CONCLUSIONS

Assessing the biological and dynamical characteristics of anchovy population (n = 20 910) as well as the size and maximum sustainable yield (*MSY*) in the Middle and partly in the North Adriatic Sea (Dalmatia) during 1974-1990 period, we found the following:

Based upon the results of the analyzed anchovy morphometric characteristics from different parts of the East Adriatic, it is possible to conclude that there were no differences between them. Comparing all the analyzed anchovy dimensions presented in the total length percentage of this species, a decrease of all the values except body height has been noticed. That value exhibited a gradual, very slight increase.

In the research period the overall anchovy length from both the coastal waters and the open sea samples from the East Adriatic ranged between 7.5 and 18.7 cm and mean length ranged between 11.0 and 16.8 cm. Samples of catches from the open sea comprised anchovy of greater mean length (14.9 - 16.8 cm) than those from the coastal waters. Differences in anchovy size indicate a certain relationship between the size of the fish and the depth of the area where they occur.

The amplitude of anchovy length varied in some coastal water samples, while in the open sea area it had a more uniform character. The coefficients of anchovy length variability were also lower in the deep sea waters, indicating the existence of a more homogeneous anchovy population in the open sea than in the coastal zone. Younger and smaller anchovy immigrate and remain in the coastal waters at the end of spring and during summer. The dominating influence of anchovy year class strength was recognized in certain years of the research period, and brought about greater contribution in succesive years of anchovy age.

The differences in mean lengths between sexes were small. As the differences in some catches were in favour of males and in the other in favour of females, generally speaking they become equal. It is especially correct of anchovy catches from the coastal waters. No differences between them were observed concerning the range of fluctuations in length. Differences occur exceptionally in dominant modal values and mean lengths in the period of intensive sexual activity because of greater proportions of females in length classes greater than 15.0 cm. It was assumed that the differences occured due to different behaviour of sexes during the time of the most intensive reproductive activity.

In the whole material there has been established an almost equal number of anchovy males and females; males contributed 47.7 % and females 52.3%. However, differences have been found in the sex ratio in some samples of anchovy catches from the open Adriatic Sea waters. The greatest aberration in the sex ratio was in August 1976 and amounted to 60.7 % males and 39.3 % females, with the males/females ratio value of 1.5 in favour of males. In the spawning period males were predominant, whilst in the inactivity period of the sexual cycle females were predominant.

The maturity stage of gonads in March and April, as well as the increase in gonad weight and also in the gonosomatic ratio, indicate prematurity stage in the sexual cycle of anchovy in that period. Spring months represent prematurity and summer months the period of maximum sexual activity. Winter is the inactivity period in the sexual cycle of anchovy. In the prematurity stage male gonads were found to be in slightly more advanced stages than those of females.

Anchovy started to spawn earlier in the open sea waters area and reached the spawning maximum sooner than in the coastal waters, where spawning and its maximum occured a month later. Gonad weight values as well as the values of gonosomatic index were greater than in males. Sexual evolution in bigger anchovy specimens from the open sea waters took place earlier than in smaller ones from the coastal water areas.

It has been found that anchovy from 0+ to 4+ years of age inhabit the Middle Adriatic Sea. Age groups 1+ and 2+ were most prominent in the exploited part of the population. They reach the asymptotic length in their fifth (4+) year of life. The fastest growth in anchovy occurs during the first three years of life. Growth rate $K = 0.57$. The obtained growth equations are as follows:

$$l_t = 19.4\ [1 - e^{-0.57\,(t + 0.5)}]$$
$$w_t = 34.8\ [1 - e^{-0.57\,(t + 0.5)}]^{3.0}.$$

Overlapping of lengths are most evident in age groups 2+ and 3+.

The analyzed lengths indicate that anchovy reached 98% of the maximum possible growth in length. According to the growth structure of anchovy population it has been concluded that older anchovy mainly inhabit the open sea.

The highest total mortality rate was found in the youngest anchovy individuals, whereas their survival rate was the lowest . The average annual mortality was A = 61 % and the natural mortality of anchovy population M = 0.65. Relatively high total mortality coefficient value Z= 1.183 is evident. Fishing mortality (F= 0.53) has a lesser influence on total mortality. The exploitation rate has an intermediary value (E= 0.45).

During their life span anchovy gradually migrate from the coastal zone towards the open sea waters, which is indicated by the difference in anchovy age composition between the coastal and the open sea waters.

Taking into consideration the analyses of annual and monthly anchovy catches, the main characteristic of the East Adriatic catches was stated to be the high contribution of small pelagic fish ranging between 66 and 85% (period 1950 - 1989). The contribution of anchovy was 0.8%. The annual fluctuation of catches is expressive in this species. The catch ratio ranged between 1:18.23 in the period 1947 - 1989, with a 70% variability and a slight tendency of an increase (27.34 tons). Comparing these anchovy catches with the West Adriatic coast ones, a coincidence tendency is noticeable among them starting in 1975, which was not the case in the period 1966 - 1975.

Anchovy are caught all the year round. The highest catches are achieved at the end of summer, especially in September, when almost one half (48%) of the total catches is realized. It is the period of structural changes due to migrations, as well as the period of intensive spawning and the most pronounced aggregability, of more intensive feeding and the increase of mesenteric fat in the visceral cavity.

The estimation of anchovy population size and maximum sustainable yield (MSY) show that this species could have been exploited more than they had been exploited in Kaštela Bay throughout the whole of the observation period with the exception of 1979. The same refers to the anchovy catches from Dalmatia region in certain years of the observation, especially during 1976 and 1978 period. The fluctuation of anchovy population size and along with it the quantity of maximum sustainable yield reflected poorly upon the size of the achieved catches in Dalmatia region. The level of exploitation maintained at the average catch of 1000 tons throughout the period, except for the year of a drastic decrease in anchovy population (1975), when the achieved catch was below maximum sustainable yield.

Considering the biological characteristics of anchovy in the research period, it seems possible that no biological factor of negative influence due to anchovy exploitation existed, although the need of a better anchovy stock management was pronounced.

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Accepted : 15 May 2000

Brgljun, *Engraulis encrasicolus* (LINNAEUS, 1758): model istraživanja biologije, dinamike populacije i njegova iskorištavanja

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SAŽETAK

U ovom su radu prikazani rezultati izučavanja biologije, dinamike populacije i gospodarstvenog iskorištavanja brgljuna *Engraulis encrasicolus* na materijalu (*n* = 20910) sakupljenom u srednjem i dijelu sjevernog Jadrana (Dalmacija) u razdoblju 1974-1990.

Osnovni je cilj ovih istraživanja bio dobiti elemente neophodne za procjenu obimnosti i biološki maksimalno dozvoljene razine iskorištavanja populacije brgljuna. U tu su svrhu studirane biološke i dinamičke značajke populacije ove vrste, njezin identitet, migracije, sastav populacije glede dužine, starosti i spola, rast, smrtnost i preživljavanje.

Ispitivanja identiteta su pokazala da u istraživanu području obitava jedinstvena populacija brgljuna, bez uočenih razlika koje bi upućivale na moguće postojanje subpopulacija.

Struktura glede dužine, starosti i učestalosti spolova je pokazala da manji i mlađi brgljun preferira priobalno područje, zbog povoljnijih hranidbenih uvjeta, zahvaljujući višim vrijednostima i gustoći fitoplanktona tijekom proljeća i ljeta, ali i kvalitativno-kvantitativnim odnosima u zooplanktonskoj zajednici u tom dijelu godine. Tada se brgljun mrijesti, a na takav je način osigurana kvalitetna ishrana roditeljskom stoku, ranim razvojnim stadijima brgljuna i imigrantima; krajem proljeća i ljeti brgljun migrira prema obalnom području.

Vrijednosti prosječnih dužina i starosti pokazale su porast od priobalja prema otvorenu moru. Transverzalni gradijent veličine i starosti brgljuna se doveo u vezu s migracijom brgljuna tijekom života - od obalnih prema otvorenim područjima. S time u svezi izgleda da je područje otvorenog mora povoljnije za starije i veće jedinke ove vrste.

Na pučini obitava i kompaktnija populacija brgljuna nego u obalnom području.

Ujednačena zastupljenost spolova je u cjelini prisutna, iako su mužjaci brojnošću dominirali u vrijeme mriješćenja, a ženke izvan tog razdoblja.

Tijek spolna ciklusa brgljuna je praćen na nekoliko načina : praćenjem stupnjeva razvoja gonada, kolebanja težine i gonosomatičnog odnosa (gonosomatični indeks). Uočeno je da spolno sazrijevanje započima u proljeće a krajem proljeća i tijekom ljeta se brgljun mrijesti. U jesen nastupa prestanak mriješćenja i mirovanje u spolnu ciklusu. Početak i maksimum razmnožavanja nastupaju ranije u otvorenom nego u priobalnom području. Isto vrijedi i za veće jedinke.

Korištenjem konceptualnih matematičkih metoda, temeljem stope rasta pri povećanoj starosti, izračunate su vrijednosti parametara rasta brljuna prema jednadžbi von BERTALANFFY-a. Vrijednosti izračunate na taj način su sljedeće : L_∞ = 19,4 cm; W_∞ = 34,8 g ; K = 0,57 god. $^{-1}$ i t_0 = - 0,5 god. $^{-1}$.

Parametri dužinsko - težinskog odnosa su : a = 0,0040 ; b = 3,0. Ovi iznosi predstavljaju temeljne podatke modela procjene veličine populacije brgljuna i njegova sustavnog gospodarenja.

Obilježja rasta brgljuna su se odrazile na dužinu životnog ciklusa brgljuna (od 0 do 4+ godina), ali i na njegov reprodukcijski potencijal. Dobne grupe 1+ and 2+ su prevladavale u lovinama.

Izračunati koeficijenti smrtnosti imali su sljedeće vrijednosti: ukupna smrtnost Z = 1,183; prirodna smrtnost M = 0,65; ribolovna smrtnost F = 0,53 uz nivo eksploatacije E = 0,45.

Uspoređujući vrijednosti procijenjene količine i biološki optimalne razine iskorištavanja s ostvarenim količinama lovina brgljuna u Kaštelanskom zaljevu i području Dalmacije, zaključeno je da se ovom vrstom nije smisleno gospodarilo u pojedinim godinama istraživanja te je iskazana potreba njezina pravilnijeg gospodarenja.