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CONTRIBUTION TO THE KNOWLEDGE OF ECOLOGY OF GREY MULLET *LIZA* (*LIZA*) *RAMADA* (RISSO, 1826) FROM THE MIDDLE ADRIATIC (ŠIBENIK AREA)

PRILOG POZNAVANJU EKOLOGIJE CIPLA *LIZA (LIZA) RAMADA* (RISSO, 1826) U PODRUČJU SREDNJEG JADRANA (ŠIBENSKI AKVATORIJ)

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A study of biological characteristics of *Liza (Liza) ramada* was carrried out over a period of one year in Šibenik area, including the observations of juveniles and their seasonal length distribution. Sexual cycle and migratory fehaviour of this species were analyzed as affected by hydrological properties of the environment. Length distribution, length-weight relationship, growth and mortality were studied for population characteristics.

INTRODUCTION

Species of mullet *(Mugilidae)* family are widely distributed and exploited all along the eastern Adriatic coast, from Piran in the north to the estuary of Bojana River in the south. Annual catch of all mullet species has been estimated, as a 15 year mean, at 280 tons. However, it may be assumed to be double that estimated.

Morović (1957) and Šoljan (1965) suggested that *Mugilidae* family is represented by six species in the Adriatic. After generally accepted revisions of the classification of this family made by Trewavas (1973) these species are: *Mugil cephalus cephalus* (L), *Liza (Liza) ramada* (Risso), *Liza (Protomugil) saliens* (Risso), *Liza (Liza) aurata* (Risso), *Chelon labrosus* (Risso) and *Oedalechilus labeo* (Cuv.). Among these species, thinlip grey mullet *Liza (Liza) ramada* is reported to occur in greatest numbers along the eastern Adriatic coast (Morović, 1976). This species was constantly pre-

sent in the catches from Šibenik Bay, area traditionally known as a rich fishng ground for grey mullet species. As to the hydrography it is characterized as a bay with significant gradients of water temperature and salinity due to the influence of fresh water from river Krka and adjacent sea.

Ecology of adult and juvenile stages of the Adriatic mullet species has generally been poorly studied (Drecun, 1956; Morović, 1953, 1954, 1957, 1961, 1964; Gandolfi and Orsini, 1970; Katavić, 1980). Moreover, *L. ramada* have not been studied separately by now. Owing to a rather great commercial importance of mullet species in the fisheries of the eastern Adriatic, particularly that of *L. ramada,* this paper is an attempt to study some of their biological properties. Contributing to the knowledge of their ecology will further make possible rational management of their population in the Šibenik area.

MATERIALS AND METHODS

The data for biological characteristics of grey mullet population in the Šibenik Bay were collected over a period of one year, from January 1984 to February 1985.

Hydrographic data were obtained from five fixed stations by classical methods. Plankton samples were taken from six stations (Fig. 1) by vertical hauls of »Hensen« type net from bottom to surface at towing speed 0.5 m/sec. Samples of juvenile mullet stages were taken appoximately monthly from five stations in the wider Šibenik area. Temperature and salinity were also measured at the same stations. Mullet juveniles were caught by a beach

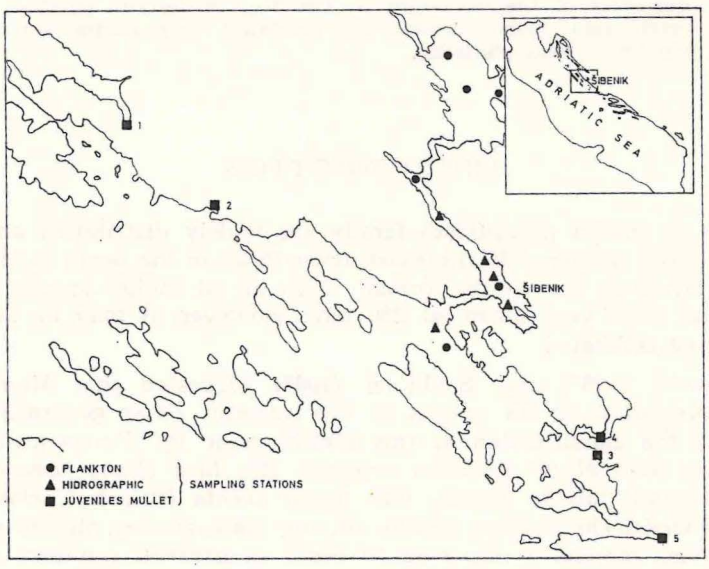

Fig. 1. Study area

seine net, 25 m long, 5 mm mesh size. Samplings were made on a monthly basis and samples preserved in 4% fomaldehid for further analyses in the laboratory.

Samples of about 100 specimens of adult grey mullet were taken from experimental catches twice in a month's period. Biological data recorded were: total length (mm), weight (g), sex, gonad maturity stage and gonad weight. Method of analysis of length frequency distribution by the use of probability paper (Cassie, 1954) was applied for the determination of fish age. Growth was calculated by exponential von Bertalanffy's equation modified after Beverton and Holt (1957). Ultrasonic detection for the estimation of population distribution and migration was carried out by EK 38A sounder and »Kelvin Huges« detector.

RESULTS AND DISCUSSION

Spawning

Eggs, larvae and postlarvae were not recorded from the study area as expected since it is well known that *L. ramada* and other mullet species spawn in the open sea upon migration from the coastal area.

Gonad maturity stage, gonad weight and gonadosomatic relation in all the individuals of *L. ramada* analyzed up to now have shown inactive stage of sexual cycle. However, gonads of specimens caught in January and early February 1984. showed characteristic signs of spent condition. On this basis it may be assumed that *L. ramada* spawn in winter up to January.

Time and area of *L. ramada* spawning have not been sufficiently studied so far.

Morović (1957, 1961) suggested the spawning of this species in the Adriatic to occur in December when this author found completely ripe specimens. Analyzing temporal length frequency distribution of juvenile mullet Katavić (1980) reported their spawning season to begin in December and last probably to February. Zaky Rafail (1968) studied gonad maturity stages in *L. ramada* from the Mediterranean waters west of Port Said. This author concluded that spawning season began in October and proceed to January being most intensive in November and December. *L. ramada* from Tunisian walters spawn mainly in November and December and ripe individuals were recorded both in October and January (Farrugio, 1975). After El-Maghraby *et al.* (1974) spawning season of *L. ramada* from Egyptian coastal waters of the Mediterranean begins in October and terminates in January.

Spawning migration

Period of gonad prematuration in *L. ramada* begins at the end of summer (Farrugio, 1975; El-Maghraby, *et al.*, 1974) It was observed that just in this period fish were rather difficultly caught from the Šibenik Bay, already in August. Observed fish showed signs of restlessness and could be easily excited. This increased sensibility seems to be connected with the

beginning of sexual maturation. It should be pointed out that no ripe individuals were recorded during the researches.

Grey mullet left the study area at the beginning of autumn. In January, after finishing spawning, the fish returned back to the Bay, when their presence was registered.

It is held that salinity is the main cause of initiation of mugilidae spawning migration, since sexual cells may complete sexual maturation only within defined salinity ranges (Gandolfi and Orsini, 1968; Farrugio, 1975). Therefore *L. ramada* as well as other species of mugilidae are forced to migrate offshore to accomplish gonad maturation.

Anyhow, hydrographic properties of the environment affect the development of sexual cycle in *L. ramada* and accordingly their offshore migrations as it may be concluded by the following hydrographic parameters recorded inside the Bay in the course of this study:

Annual mean salinity varied from 6.6 to 27.2‰. However, the ragne of extreme values is far wider, with minimum 0.57‰ and maximum 38.03‰. Minimum surface salinity was recorded from all the stations in October and maximum surface salinity in February. From the beginning of the year to the end of summer the salinity gradient increased with depth, from 5 to 30 m, thus that the highest salinity was recorded from 30 m depth. With the beginning of autumn salinity began gradually to increase towards the surface layers. Thus maximum salinity was measured at 20 m in October and at 10 m in December.

Surface temperature varied from 8.42°C at the end of winter to 24.74°C at the end of August. Monthly mean temperature measured in January was 12.01°C to increase to 20.56°C at the end of summer. Similar high mean temperature was obtained in October (20.15°C) but surface temperature dropped to 16.62°C while in other layers temperature was 4 to 5 degrees higher. In December temperature dropped to about 16°C.

Surface layer of the water in this area is sufficiently aerated owing to the River and its waterfalls. The highest oxygen values were recorded from January to March and the lowest values were measured in the intermediate layers in October.

Changes of controlled hydrographic factors, that is gradually increased salinity, rather pronounced thermocline and decrease of aeration recorded from the Šibenik Bay in early autumn coincided with the offshore migration of *L. ramada* from this area to open sea. This is indicative of great influence of physical-chemical environmental factors on the development of sexual cycle and migratory behaviour in *L. ramada.*

Juvenile stage

Juveniles of all the mullet species present in the Adriatic were recorded. A total of 3262 individuals of juvenile mullet were identified. Of these *L. ramada* made up, on the average, 14.6%. Temperature of the areas wherefrom juvenile *L. ramada* were caught, showed great variations, from 2.8°C in winter to 27.2°C in summer. Salinity ranged from 4.45‰ to 37.36‰ (Table 1).

Table 1. Environmental characteristics of juvenile mullet sampling localities in January 1984 — February 1985 period

Station	Bottom type	Maximum depth (m)	T°C range	Sal ‰ range
1	Muddy-sandy	0.5	2.8 — 25.3	20.52 — 37.36
2	Muddy-sandy	1.5	12.1 — 25.1	17.07 — 27.56
3	Sandy	1.5	8.8 — 27.2	37.70 — 38.80
4	Muddy-sandy	1.5	8.8 — 27.3	20.17 — 35.38
5	Muddy	1.0	13.1 — 20.2	4.54 — 26.42

Wide ranges of salinity and temperature are indicative of the high tolerance of juvenile *L. ramada* to different environmental factors and their variations in time. It is interesting to mention that no juvenile *L. ramada* were recorded from station 3 characterised by high salinity because of lack of fresh water inflow.

The first occurrence of juvenile *L. ramada* was recorded not earlier than in March when they made up 17.9% of captured juvenile mullet individuals. Juvenile *L. ramada* constituted about a third of the total number of juveniles in the April, May and June catches. The number of individuals thereupon was decreased not to exceed 14.1% of the total number of caught individuals at the end of August.

Length frequency distribution of juvenile stages of *L. ramada* is given in Fig. 2. Mean length of juvenile individuals caught in March was 26.96 mm. Even though length distribution was very similar during the two following months, very likely due to a continuous arrival of new younger individuals, a trend of juvenile length increase of about 5 mm per month may be observed. The April mean was 30.65 mm and the May one 31.64 mm in total length. Mean length was 34.88 mm in June, 40.95 mm in July. When juveniles occurred for the last time in the catches, mean length was as high as 46.80 mm. Maximum measured length was 57 mm.

Postlarvae and juvenile stages of mullet search for the sheltered coastal areas, where feeding conditions are more favourable, very early. Even though juvenile *L. ramada* was recorded from the samples for the first time in March it may be assumed that they arrive to the coastal waters earlier as well, that is during January and February. It should be pointed out that smaller individuals are not retained by the gear used. The mentioned assumption may account for the fact that the reproduction period and occurrence of juveniles did not coincide. Similarity of length distribution during the first three months of occurrence of juveniles indicates that migratory season towards the coastal waters extends by May.

These results are in agreement with those of Katavić (1980). Studying temporal distribution od *Mugilidae* juvenile stages on the eastern coast of the middle Adriatic in 1978—1979 this author found *L. ramada* juveniles to be present in the Split area from March to September, with the initial length range 23—32 mm attainig finally 44—99 mm range. This author also suggested that juveniles occurred for the first time along the coast even earlier. Bograd (1961) reported the migration of juvenile *L. ramada* from the

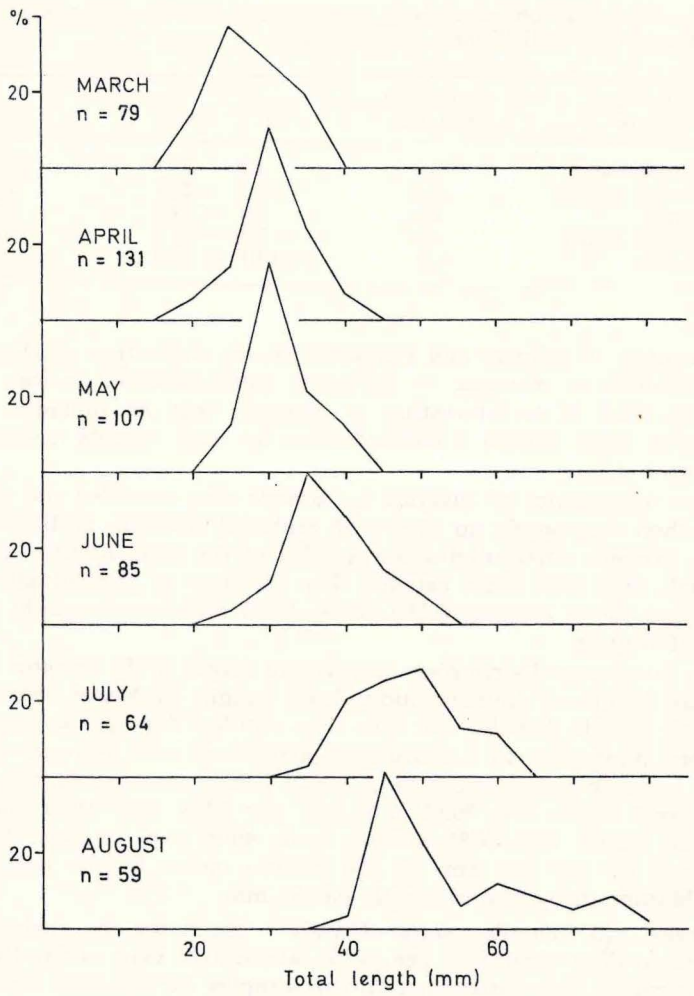

Fig. 2. Length frequency distribution of juvenile *Liza ramada* sampled in the Šibenik coastal area in 1984

open sea towards the Mediterranean coast of Israel to begin about the middle of January and extend up to the beginning of May. They are confined to the coastal area by September.

Adult stages

Length and weight data were obtained from 754 adult *L. ramada* specimens worked out, ranging from 28.0 to 51.0 cm in total length. Mean total body length was 38.9 cm. The individual weight varied within 171.5 and 993.1 g. The study of the sex of adult grey mullet during this period

showed that the proportion of females (61.3%) in general exceeded that of males. Histogram of length distribution shows that dominant modal values are somewhere between 36 and 44 cm referring to the best represented year classes (Fig. 3). Six age groups, from the third to the eighth one, were determined by length frequency analyses.

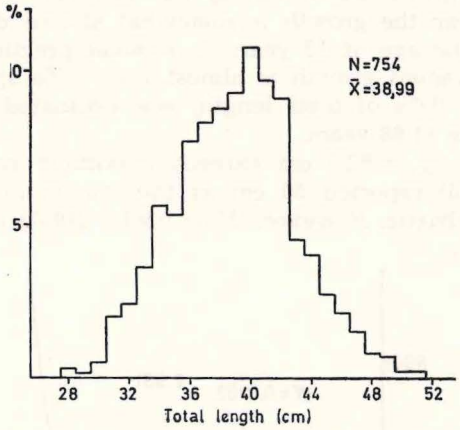

Fig. 3. Length frequency distribution of adult *Liza ramada* specimens taken from the catch in the Šibenik Bay in January — September 1984

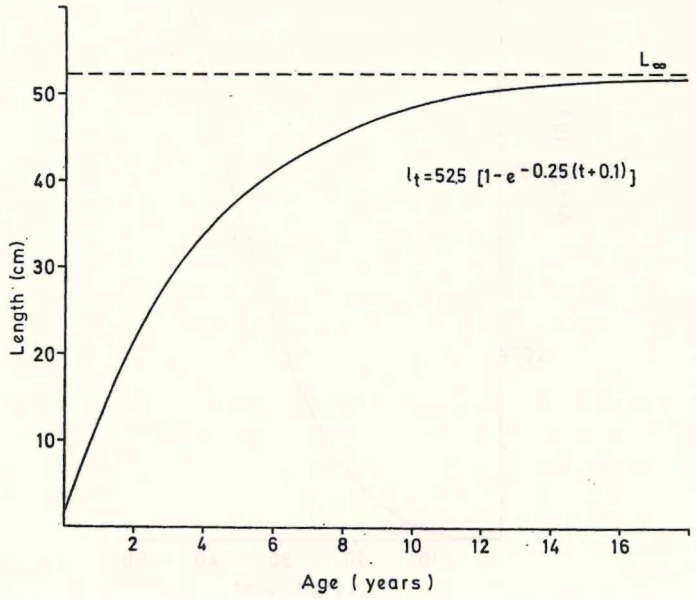

Fig. 4. Growth curve of *Liza ramada* from the middle Adriatic Sea

Values of growth parameters obtained by Ford-Walford method from mean *L. ramada* lengths at a defined age are $L_{\infty} = 52.5$ cm, $K = 0.25$. The value $t_0 = -0.1$ was deduced from preceding parameters. These values were introduced into the exponential growth equation by means of which the theoretical growth curve given in Fig. 4 was fitted. It is obvious that this mullet species grows faster during the first and second years of age. Up to the fourth year the growth is somewhat slowed down to stabilize in the sixth year. At the age of 12 years *L. ramada* practically grow no more which means that annual growth is almost zero. Life span, that is the age at which fish attain 95% of their length, was estimated by the equation of Taylor (1962) to be 11.98 years.

Obtained value $L_{\infty} = 52.5$ cm exceeds maximum recorded length (51.0 cm). Šoljan (1965) reported 50 cm as the maximum length this species may attain in the Adriatic. However, Morović (1957) mentioned maximum

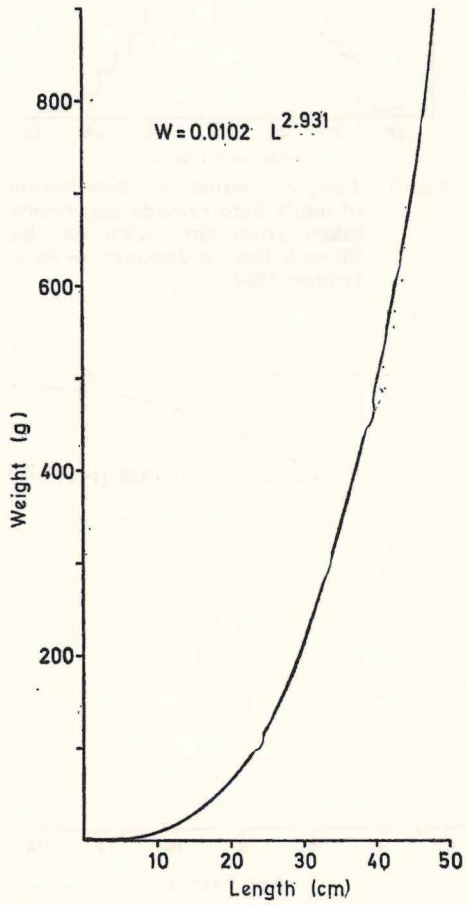

Fig. 5. Weight-length relationship of *Liza ramada* based on 754 fishes from the Šibenik Bay

length of 40 cm. As reported by Cataudella *et al.* (1984) *L. ramada* attain maximum length of 55 cm in the Mediterranean while Ben-Tuvia (1973) recorded 60 cm. Farrugio (1975) calculated growth parameters for *L. ramada* from Tunisia. However, he based his calculations on standard length which makes difficult the comparison with the above results based on total length. This author suggested that growth process of these fish terminated at about ten years of age. Quignard and Autherm (1981) computed von Bertalanffy growth parameters for age-length data based on scale reading, for different age groups. Their values are lower than ours, except those for the 0—8 age group of females which are greater.

Length-weight relationship was examined by allometric equation $W = aL^b$, where W is the fish weight, L total length, b index of equilibrated increment and a is a constant. Length-weight relationship for the total number of individuals of both sexes is expressed as:

$$W = 0.0102\ L^{2.931}$$

the expression used for the calculation of theoretical weight values for every length given in Fig. 5. Obtained values show slow negative allometry that is that growth to length exceeds the gain in weight. This relationship refers to sexually mature individuals caught during resting stage of sexual cycle.

Value of asymptotic weight $W_{\infty} = 1122.98$ g was calculated from mean weight values at a defined age. The use of length-age and weight-length relationships renders possible a determination of respective weight at a defined age by the following function:

$$W_t = 1122.98\ [1 - e^{-0.25\ (t\ +\ 0.1)}]^{\ 2.931}$$

Zaky Rafail (1968) found very similar index of equilibrated growth increment ($b = 2.914$) for *L. ramada* from the Egyptian Mediterranean coast. The indices $b = 2.83$ for females and $b = 2.04$ for males were calculated on the basis of standard lenght for the population of the Tunisian Mediterranean coast (Farrugio, 1975). Quignard and Autherm (1981) give length-weight formulas that they obtained for grey mullet from Languedoc area of the west Mediterranean. Their data refer to standard length, for males, females and sexes combined out of the spawning season. However, after corresponding conversion, ponderal growth indices all agree well with those based on the data from this study.

Population parameters

Biometric characteristics of *L. ramada* caught from the bay, that is total length and maximum body girth were studied so as to determine which appropriate fishing gear to apply for their fishing in this area (surrounding net for mullet). These two values gave the ratio value of 0.5 which was used to calculate selectivity factor by the nomogram approach (Pauly, 1983), which in this case was $SF = 3.3$. Consequently, value $l_c = 18.0$ cm of total length was estimated. Namely, the grey mullet specimens of 18.0 cm had a 50%

chance to be retained by the net that was used for the purpose of this study with 28 cm mesh size (56 mm diagonally) of the webbing.

Natural mortality of *L. ramada* in the Adriatic and the Mediterranean in general has not been estimated up to now since it is not easy to obtain the necessary data for direct assessment because of the population structure and poorly known migrations of the population. However, the values of mortality index which may be taken as fairly reasonable were calculated from the parameters obtained by this study. Namely, Pauly (1983) obtained an approximative index of natural mortality on the basis of von Bertalanffy's growth parameters and annual mean water temperature. The mean measured temperature in the Šibenik Bay (14.76°C) introduced in Pauly's equation gave natural mortality $M = 0.241$. On the other hand it was calculated $M = 0.252$ by the method based on the fish life span (Taylor, 1962). Both these estimates are pretty good if it is taken into account that *L. ramada* is a species of medium life span living in schools. A comparison of abundance index at the beginning of our study to that at the end (Gulland, 1964) gave the index of total mortality $Z = 0.689$.

Total and fishing mortality, rates of survival and exploitation were calculated separately for each year class (Table 2) by the analysis of length and age structure of the population (Jones, 1981).

Table 2. Values of population parameters of *Liza (Liza) ramada* for every age class

Interval	Total mortality	Rate of survival	Fishing mortality	Exploitation level
3+ to 4+	0.29	0.748	0.09	0.638
4+ to 5+	0.61	0.543	0.41	0.749
5+ to 6+	1.27	0.281	1.07	0.814
6+ to 7+	1.03	0.357	0.83	0.741
7+ to 8+	0.76	0.468	0.56	0.626

The highest mortality indices were recorded for age groups 5 + and 6 +. Age groups 4 + and 5 + showed the highest exploitation levels. This means that these groups of *L. ramada* showed greatest vulnerability. On the other hand, younger part of the population showed higher survival rate.

Catch characteristics

Adult specimens of the species *Liza (Liza) ramada* were the main component of the catches from the Šibenik Bay. *L. ramada* was present in the catches from their third to eight year of age (Fig. 6). The highest proportion (74.7%) was made up by the specimens of 4 + and 5 + age groups. These fish represent the exploited part of the population accessible to the surrounding mullet net, whereas majority of the fish remained at sea three years old and younger (Fig. 7).

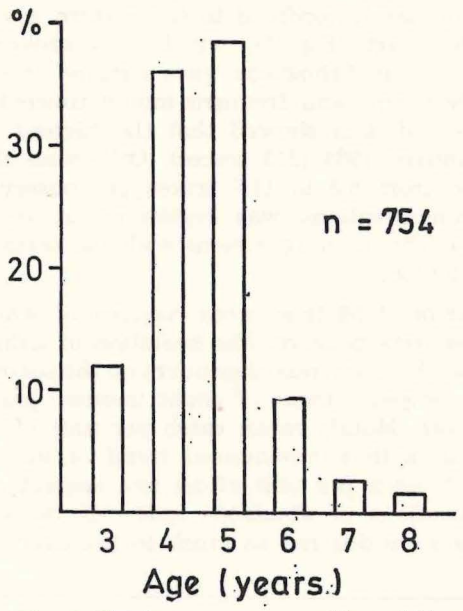

Fig. 6. Catch — age composition of *Liza ramada* from the Šibenik Bay in 1954

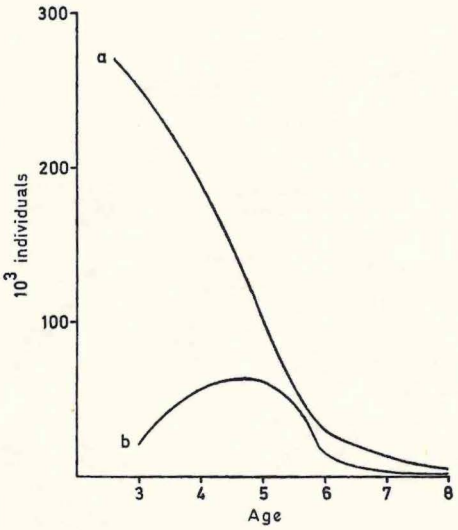

Fig. 7. Relation between average number of specimens (a) and the number of removals by catch (b) grouped by age, for *Liza ramada* stock from the Šibenik Bay in 1984

Grey mullet were mainly confined to the eastern coast of the bay, closer to its most inhabited part (Fig. 8), which was proved by echograms of ultrasonic detectors as well. Echograms gave data on the presence of sometimes very dense, rather large and frequent mullet concentrations in the Šibenik Bay. The analysis of data showed that the highest concentrations were recorded later in January 1984 (215 traces). Otherwise the number of trace concentrations varied from 6.5 to 11.7 traces per observation. Exceptionally small number of concentrations was registered at the end of 1984 and the beginning of 1985. This is in agreement with the season of mullet offshore migration for reproduction.

During the experiment 56 trips were realized of which only those from January to September were positive. The evolution of fishing effort, expressed as the number of search hours was dependent on the searching for fish schools. However, the effort showed a trend of slight increase particularly during the second part of the year. Montly mean catch per unit effort was 153,43 kg/h of searching per boat, with a pronounced trend of decrease of 24.28 kg/h. Monthly variations of catch per unit effort and respective fishing effort are given in Fig. 9. Variations of abudance index of the exploited population part and its decrease were due not so much to the overfishing as to the fish

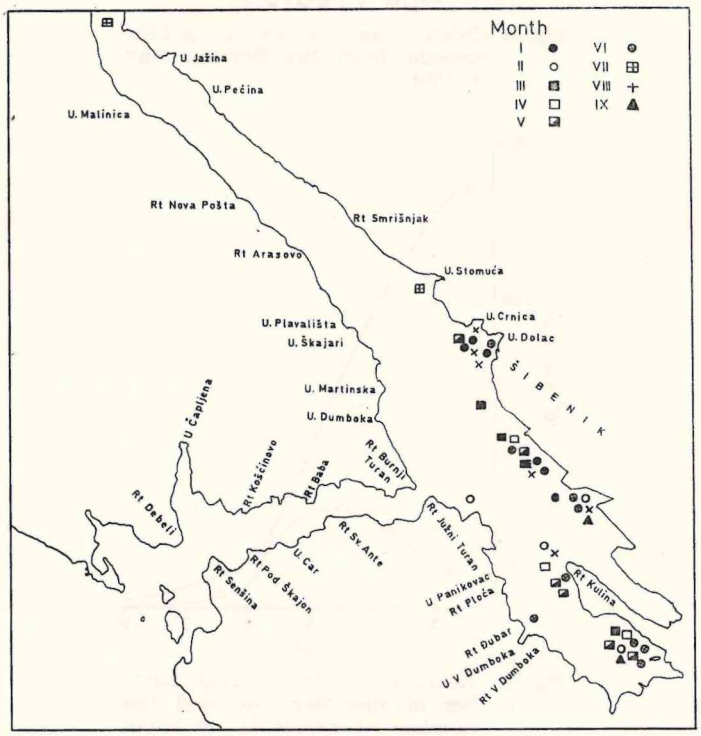

Fig. 8. Distribution of the catch sampled from the Šibenik Bay in 1984

migration for spawning. Monthly variation of CPUE and fishing effort given in the Figure 7 show a proper development during experimental fishing ($r = 0.755$, $P < 0.5$), what in a way supports the conclusion arrived at.

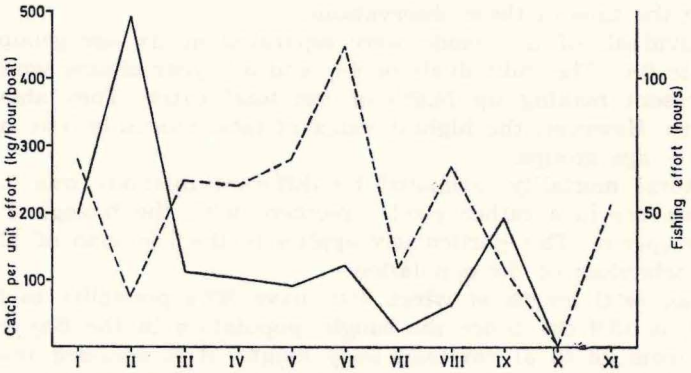

Fig. 9. Monthly fluctutations of catch per unit effort (———) and fishing effort (— — — —) for *Liza ramada* stock from the Šibenik Bay in 1984

CONCLUSIONS

The results of a year study of biological characteristics of *Liza (Liza) ramada* during their occurrence in the Šibenik Bay showed the following:

— The analysis of gonad state and the occurrence of juveniles showed that the spawning season of *L. ramada* extended at least over December and January. At the beginning of February gonads showed the spent condition.

— Juvenile *L.ramada* were not recorded from the catches earlier than at the beginning of March. The smallest individuals recorded had the mean length 26.96 mm. The growth process from March to May appeared to be slower than expected which was probably due to the amply extended migrational period of juvenile fish to the coastal waters.

— *L. ramada* were accessible to fishing during the period of sexual inactivity from late January to September. Accessibility was considerably reduced at the beginning of autumn when fish began to migrate offshore for spawning.

— Changes of controlled hydrographic factors recorded from Šibenik Bay at the beginning of autumn coincide with the disappearance of *L. ramada* from this area. This is indicative of a strong influence of physical — chemical enviromental factors to the sexual cycle development and migratory behaviour of these fish.

— The following values of von Bertalanffy's growth parameters were estimated: $L_{\infty} = 52.5$ cm, $K = 0.25$ and $t_o = -0.1$. *L. ramada* attain maximum length at 12 years of age.

— The weight — length relationship show negative allometry during the time of sexual inactivity. Ponderal growth index was 0.2931 and the asympto-

tic weight 1122.98 g. The values obtained by a comparison of the maximum total length and weight of grey mullet from the samples to the asymptotic values of their total length and weight are indicative of the fact that 97.1% of potential growth in length and 88.4% of potential growth in weight were achieved at the time of these observations.

— Individuals of *L. ramada* were separated in six age groups with the range 3+ to 8+. The individuals of 4+ and 5+ year classes were most frequently present making up 74.6% of the total catch. They showed higher vulnerability. However, the highest index of total mortality was recorded for 5 + and 6 + age groups.

— Natural mortality estimated by different methods was 0.24 to 0.25. These values are in a rather good agreement with the biological characteristics of the species. This particularly applies to the life span of 12 years and migratory behaviour of the population.

— Mean total length at which fish have 50% possibilty to be retained by the net, is 18.0 cm. Since the caught population in the Bay consisted of specimens from 28 to 51 cm total body lenght, it is assumed that normally used type of fishing net does not exert any harmful effect to grey mullet exploitation in the Šibenik Bay.

— In this case the variations of catch per unit effort and its decrease during the experiment were due not only to the fact that this fish population had got exploited but also to the migration.

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PRILOG POZNAVANJU EKOLOGIJE CIPLA *LIZA (LIZA) RAMADA* (RISSO, 1826) U PODRUČJU SREDNJEG JADRANA (ŠIBENSKI AKVATORIJ)

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KRATKI SADRŽAJ

U radu se donose rezultati jednogodišnjih istraživanja bioloških karakteristika cipla balavca *Liza (Liza) ramada* (Risso, 1826.) i dinamike njegove populacije u Šibenskom akvatoriju, gdje je u lovinama cipla najzastupljenija vrsta. Podaci su se sakupljali od siječnja 1984. do veljače 1985. godine.

Mlađ cipla *L. ramada* je bila prisutna u lovinama od ožujka do kolovoza. Srednja dužina u tom razdoblju iznosila je od 26,96 mm do 46,80 mm. Pojava mlađi cipla balavca te njezina dužinska raspodjela povezana je s periodom razmnožavanja ove vrste.

U Šibenskom zaljevu je odrasla *L. ramada* dostupna izlovljavanju za vrijeme spolnog mirovanja, tj. od siječnja do početka jeseni. U tom vremenu hidrografske karakteristike bazena variraju u širokom rasponu, a značajnije promjene registrirane su najviše tokom mjeseca listopada, što se inače podudara s reproduktivnom migracijom te vrste.

Izračunata je teoretska krivulja rasta uvodeći u von Bertalanffy-jevu eksponencijalnu jednadžbu rasta vrijednosti $L_{\infty} = 52{,}5$ cm totalne dužine; $K = 0{,}25$; $t_0 = -0{,}1$. Rezultati ukazuju na relativno spori rast cipla balavca, koji dosegne 95% od svoje ukupne dužine u dvanaestoj godini života. Indeks ponderalnog rasta iznosi 0,2931.

Za određivanje starosti riba primijenjena je metoda analize distribucije dužinskih frekvencija i očitavanja otolita. Primjerci *L. ramada* su bili raspoređeni u šest starosnih klasa u rasponu od 3+ do 8+. Najzastupljeniji (74,6%) su bili prmjerci od 4+ do 5+ godina starosti. Oni su također pokazivali i veću vulnerabilnost. Mlađi dio populacije cipla balavca pokazivao je viši stupanj preživljavanja.

Procjena prirodne smrtnosti dobivena različitim metodama iznosila je između 0,24 i 0,25. Ova vrijednost se približno podudara sa biološkim karakteristikama vrste *L. ramada*, osobito sa graničnom starošću i migracionim ponašanjem njezine populacije.