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A CONTRIBUTION TO OUR KNOWLEDGE OF THE BIOLOGY AND ECOLOGY OF THORNBACK RAY *(RAJA CLAVATA* L.*)* AND BROWN RAY *(RAJA MIRALETUS* L.*)* IN THE ADRIATIC

PRILOZI POZNAVANJU BIOLOGIJE I EKOLOGIJE RAŽE KAMENICE *(RAJA CLAVATA* L.*)* I RAŽE MODROPJEGE *(RAJA MIRALETUS* L.*)* U JADRANU

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1. INTRODUCTION

As yet the study of the biological and ecological characteristics of many commercially important and widely spread Adriatic bottom fishes bas been rather incomplete. The available data refer mainly to certain narrower areas under study, which logically results in insufficient knowledge and misunderstanding of many complex biological and ecological phenomena. Two of the most frequently found Adriatic species of Rays, i. e. Thornback Ray (*Raja clavata* L.) and Brown Ray (*Raja miraletus* L.) are among the bottom fishes that have not yet been studied enough. Little is known about their age, time and manner of spawning, migration and fluctuation and the factors conditioning all this, the population density, influence of intense fishing on fish population, etc. Until now these problems were dealt with individually, greater attention was paid to solving some other questions, such as sex relation, the relation of body length and width of disc, the relation between these features and weight, to nourishment, distribution, etc.

Few authors have studied the biological and ecological characteristics of the above mentioned species of Rays. The most complete studies can be found in the works by Županović, (Županović, 1961 a, b) for both species and by Čanadjija (Čanadjija, 1956, 1959) for Thornback Ray. Jardas (1972) gives the ecological characteristics of these species treating especially their nourishment. Kirinčić & Lepetić (1955) give data on their relations to depth, maximal lengths and sex in the area of the deep South Adratic.

The authors that have studied the benthic fish settlements in the Adriatic, such as Kotthaus & Zei (1938) in the channels of the Croatian Littoral, Zei & Sabiancello (1940) in the channels of Dalmatia, Zei (1940, 1942, 1949) in the North and Central Adriatic, Crnković (1958) in the North

Adriatic, and others, give data on distribution, numerical and weight relations of these species obtained while conducting some wider studies on fish settlements. The biometric data are, however, rather poor.

Among the published results obtained by the fishery-biological cruise in the »Hvar« (1948/49) (K a r l o v a c, 1959) we can find the data on the distribution of these species of Ray in the Adriatic.

Some foreign research workers, such as S y r s k y (1876), G r a e f f e (1888) and others, studied some of the biological characteristics of these species of Ray in the Adriatic.

This paper deals with some of the biological and ecological characteristics of Thorbnack Ray and Brown Ray in the area of the open Central Adriatic. The author has tried to answer some of the frequently treated questions, which, according to him, have not yet been studied enough.

2. MATERIAL AND METHODS

All the samples of the Thornback Ray and Brown Ray used in this study were caught by trawls during a five years' period (1968—1972) at 21 stations placed during the cruise in the »Hvar« (M o r o v i ć, 1951, K a r l o v a c, 1956) in the Central Adriatic, and also the samples of the Thornback Ray captured with a long-line on the bars south of the islands of Biševo and Mljet (Fig. 1, Table 1). A total of 561 samples of the Thornback Ray and 141 of the Brown Ray were captured and studied. In both cases the material consisted of samples

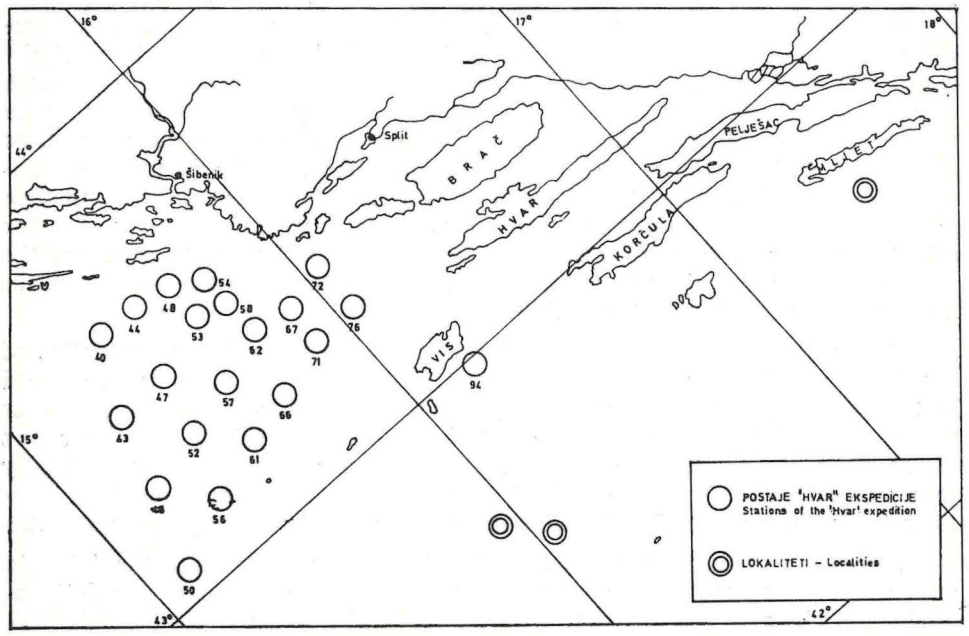

Fig. 1. Geographical position of stations and localities

of various sizes (age). All the measurements, such as the length of the body, width of disc, weight and others, were taken from fresh material. This enabled us to avoid all the inaccuracies that could have resulted from stale (partly dry) or preserved material. The measures of length and width were taken to be nearest cm above 0.5 cm, to round them off to 1 cm when elaborating the data. The weight was taken to the nearest g above 5 g.

Variatio-statistical methods were used for elaborating the data. As the measure of central tendency the mean value ($\overline{X}$) was taken, and of the variation measures the standard deviation (s) and the coefficient of variation V ($V = s \times 100/\overline{X}$). The coefficient of variation was applied to find out in which of the two biometric characteristics the species varies most and which sex varies more in the same biometric characteristic (in %). The ratio $R = 1/s$, where 1 is the greater dimensions and s the smaller one, was used to estimate how much the greater dimension (body length) exceeds the smaller one (width across the disc). The difference between the arithmetical means was tested by the standard error of arithmetic means ($s_{\overline{x}}$), whose values were used to calculate the value t, which expresses the relation between a difference and its error. The formula is:

$$t = \overline{x_1} - x_2/s_{\overline{x}\,1} - \overline{x_2}, \text{ where } s_{\overline{x}\,1} - \overline{x_2} = \sqrt{\frac{s^2_1}{N_1} + \frac{s^2_2}{N_2}}$$

$\overline{X_1}$ and $\overline{X_2}$ denote the mean values of this character, and $s_{\overline{x}\,1}$ and $s_{\overline{x}\,2}$ the corresponding standard errors. This made it possible to test the reality of the morphological differences between sexes. The difference is statistically significant if the value t is greater than 1.96.

The degree of association between two quantitatively different variables (length-width, length-weight) was obtained by calculating the correlation coefficient of the samples (r) after the formula:

$$r = \Sigma xy \,/\, \sqrt{\{(\Sigma x^2)\ (\Sigma y^2)\}}$$

where x and y denote the corresponding values of the variable X and Y.

Regression coefficient (or line) (b) for the linear regression was obtained with the formula:

$$b = \Sigma xy \,/\, \Sigma x^2$$

Here $x = X - \overline{X}$, and $y = Y - \overline{Y}$. X and Y determine the variable one of which (X — length) is taken as independent, and the other (Y — width) as dependent variable. The obtained value b shows how much the value of dependent character changes with regard to the increased value of independent character. Accordingly the slope of the regression line corresponds to the formula

$$y = bx$$

where x denotes the value of independent character.

The relation of length to weight in both elaborated species could be defined by the exponential increasing curve or the law of complex interest after the formula

$$W = A\ (B^x)$$

Where A and B denote the constants that have to be estimated, and $W = Y$. This curved ratio (curved regression) was reduced to straight lines by the rectification method so that logarithms were applied to the above mentioned expression, and

$$\log W = \log A + (\log B)\ x$$
or
$$Y = \alpha + \beta x$$

was obtained where $Y = \log W$, $\alpha = \log A$ and $\beta = \log B$. That means that if log W instead of W is used in relation to X, the graph in such an arith-long coordinate system will be linear.

3. RESULTS

3.1. *Raja clavata* L.

3.1.1. Distribution

Of 21 stations in the area of the open Central Adriatic where analyses were conducted 12 of them were positive with regard to the catches of the

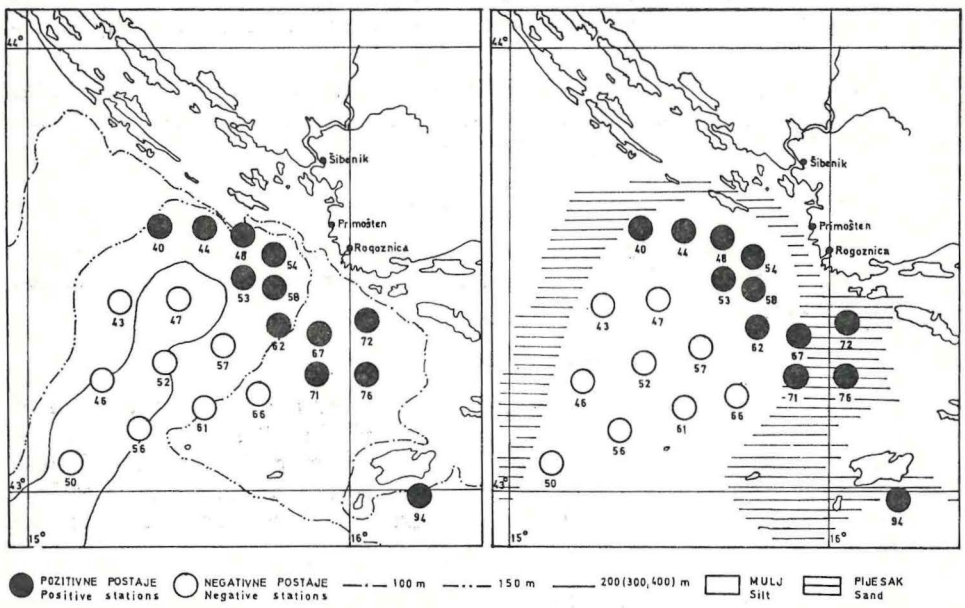

Fig. 2. Distribution of Thornback Ray in the area of the open Central Adriatic with regard to depth and character of bottom

Thornback Ray (Fig. 2, Table 1). The greatest number of samples were captured at the stations 58, 67, 71, and 72, 281 samples in all, i. e. 50%. The depths at these stations were from 112 to 160 m. The most numerous populations of the Thornback Ray were found at the stations 67, 71, and 72 whose depths were 126, 123 and 112 m respectively. At other positive stations, whose depths were generally down to rouhgly 212 m, a considerably smaller number of Rays was captured. It follows that the Thornback Ray in the area of the open Central Adriatic most often in the depths down to 160 m, with the maximal population density in the depths of from 100—130 m.

Kirinčić & Lepetić (1955) found this species in the area of the deep South Adriatic especially abundant at the depth of 100 m. At that depth 80.0% of samples were caught, at 200 m 15.6%, at 300 m 2.7%, and at 400 m 1.7% only. The last depth is also the greatest in which samples of Ray were captured. Čanadjija (1959), however, hound samples also in the depths beyond 500 m. Županvić (1961) points out that in the channel and open regions of the Central Adriatic at the depths of from 100—120 m this species predominates over all other *Chondrichthyes*. According to the results of the cruise »Hvar« (Karlovac, 1959) the Thornback Ray was caught at 142 out of 167 stations at the depths of from 30—400 m, with the maximal hauls from the depths of about 100 m (75—140 m).

The data by Berg *et al.* (1949) show that the Thornback Ray lives in depths down to 300 m, and in the Black Sea to 100 m, while the data by Smirnova (Svetovidov, 1964), also for the Black Sea, shown that it is captured in depths of from 40—70 m.

Seven out of twelve positive stations lay on the muddy (clayey, loamy or mixed) bottoms. On those supports the biocenosis *Nephrops norvegicus — Thenea muricata* (Gamulin — Brida, 1965) is present. The other 5 stations lay on the floors of sandy component and shelly elements (sandy-shelly bottom) with the zoocenosis *Turritella profunda* (Vatova, 1947 a, b). The rays were captured on both bottoms. Considering the depth and character of the bottom it was observed that these were most frequently captured on the bottoms with sandy component, i. e. at the stations 67, 71, 72, 76, and 94. As to other bottoms they were somewhat more frequently caught also on the loamy-clayey bottoms.

Županović *(op. cit.)* quotes for the channel region of the Central Adriatic that the most frequent habitats of this species are the mixed bottoms in which particles of sandy loam prevail.

3.1.2. Minimal and maximal dimensions

The largest Thornback Ray measured in the area of the open Central Adriatic was 93 cm long and 65.2 cm in width of disc. This sample was caught at the station 54 at the depth of 168 m. The largest male sample was 79 cm long and 51 cm across the disc, and the former dimensions refer to the largest female sample. The mean length of all the samples was 28.4 cm, with standard deviation s = 15.20 and 23.8 cm across the disc, with standard deviation s = = 11.85. The mean values of lengths in sexes were: 28.4 cm for males, standard deviation s = 15.03, across the disc 23.9 cm, standard deviation s = 11.69. The mean body length of the females was 28.2 cm, standard deviation s = = 15.38, across the disc 23.7 cm, standard deviation s = 12.01. The smallest

sample of the Thornback Ray caught in the same area was 10 cm long and 5 cm across the disc.

Figure 3 shows the population composition of Thornback Ray in the area of the open Central Adriatic, with regard to the number of samples per length.

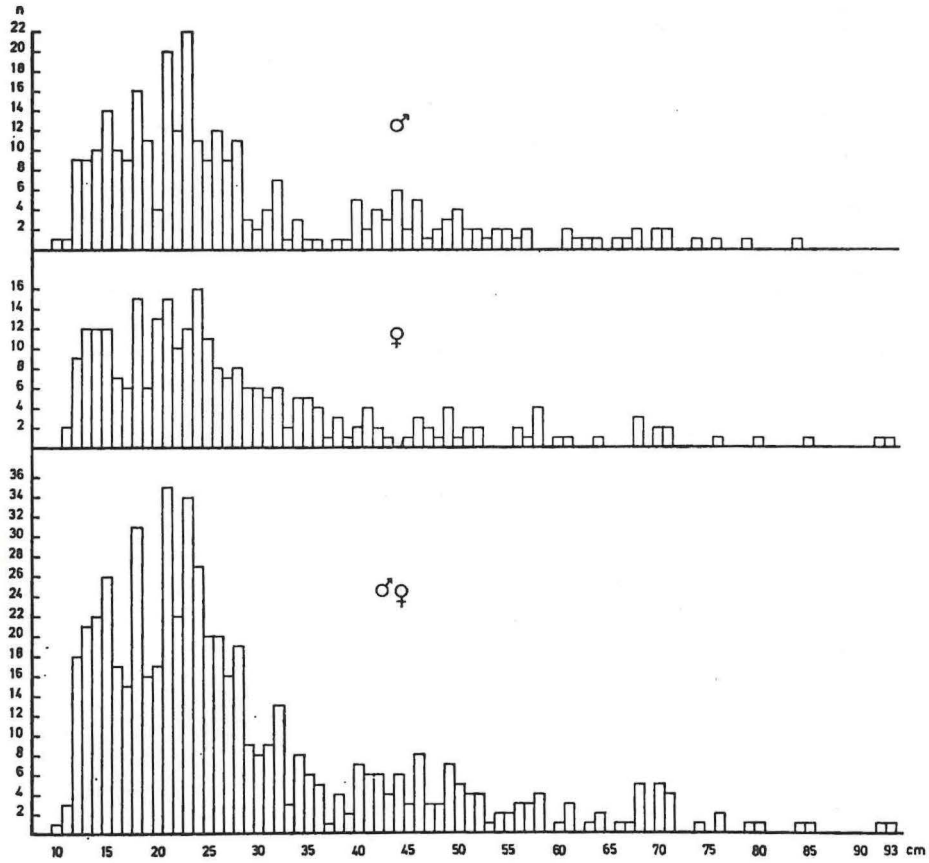

Fig. 3. Frequency of Thornback Ray's length in the area of the open Central Adriatic (1968—1972)

Šoljan (1948) quotes 75 cm as the maximal length for this species in the Adriatic. Krinčić & Lepetić *(op. cit.)* quote 98 cm as the maximal length of Thornback Ray in the deep South Adriatic. The longest male sample was 84 cm, and the female 98 cm. The authors find that the females are, on the average, about 3.4 cm larger than the males are. Čanadjija *(op. cit.)* quotes a female sample of 101/76 cm as the maximal size and 10/6 as the minimal one for the Adriatic. Županović *(op. cit.)* gives 100/70 cm as the maximal measures taken for the open Adriatic and 105/70 cm for the channel region of the Central Adriatic. He also gives the mean values of length of these characters valid for both sexes. The mean values in the channel region were 42.80/27.06 cm for males and 45.50/29.44 cm for females. The

mean dimension for both sexes were 44.03/28.22 cm. In the open area the mean dimensions for both sexes were smaller, i. e. 23.52/14.81 cm. Grubišić (1958) quotes 110 cm as the longest sample of the Thornback Ray caught in the Adriatic in the channel of the i. of Vis.

Berg, *et. al. (op. cit.)* quotes 125 cm as the greatest length this species can reach, which is also the maximal length of a female, while 70 cm is considered to be the maximum of a male. The length of the sample following immediately eclosion is 12.6/8 cm. Moreau (1881) gives 80—100 cm as the maximal length of the Thornback Ray in the French seas mentioning that it can probably grow beyond that size. Blegvad (1938) quotes 85 cm as the maximal body length and 61 cm across the disc for the North Atlantic. Clark (1926) quotes 65.8/44.0 cm as the maximal sizes for the Mediterranean (Malta, Naples) having measured only a few samples, and 77.7/55.1 cm for the Atlantic (English Channel) and 72.0/48.5 cm for the North Sea. After the same author (Clark, 1922) in the area of Plymouth the mean values of individua immediately after eclosion were 12.6/7.9 cm. In the Black Sea the maximal body lengths measured for the females were up to 125 cm and for the males 83.5 cm (Svetovidov, *op. cit.*).

Our data obtained for the open Central Adriatic are very close to those by Županović for the same area, while they somewhat differ from the data for the channel region of the Central Adriatic by the same author. These data, regarding the size of the dimensions measured, are between the above mentioned values. With regard to the maximal dimensions of the body taken for other seas they are the nearest to the data by Moreau for the French shores and Blegvad for the North Atlantic areas.

3.1.3 Ratio of body length and width across the disc

The regression line of the body length and width across the disc ratio is compared to the line of the »ideal ratio« (3:2), which had been obtained earlier by Čandjija *(op. cit.)* for the same ratio of the same species. According to this ratio the regression line should cover and coincide with the line of 3:2 ratio, i. e. the ratio between body length and width across the disc expressed in the ratio 3:2. The line determined by the ratio 1:w = 3:2 was taken for comparing the data.

The body length and width across the disc ratio for the Thornback Ray in the area of the open Central Adriatic is shown in Table 2 and Fig. 4.

The body length and witdh across the disc ratio is for both sexes distinctly linear and does not shown any morphological differences between males and females. The regression coefficient of this ratio for males is $b = 0.68$, and the correlation coefficient $r = 1$ and proportion $R = 1.55$. For females $b = 0.68$, $r = 0.9832$ and $R = 1.56$. The values for both sexes taken together are: $b = 0.68$, $r = 0.9942$ and $R = 1.54$. In all the cases the regression coefficient is $b = 0.68$, which means that to every centimeter of body length there is about 0.68 increase in widith of disc.

Variability and difference in the degree of variability of width of disc and body length has been noticed in both sexes. In both sexes the variability of body length is more significant than the variability of width across the disc is. In females the coefficient of variation of body length is $V = 54.5\%$ and

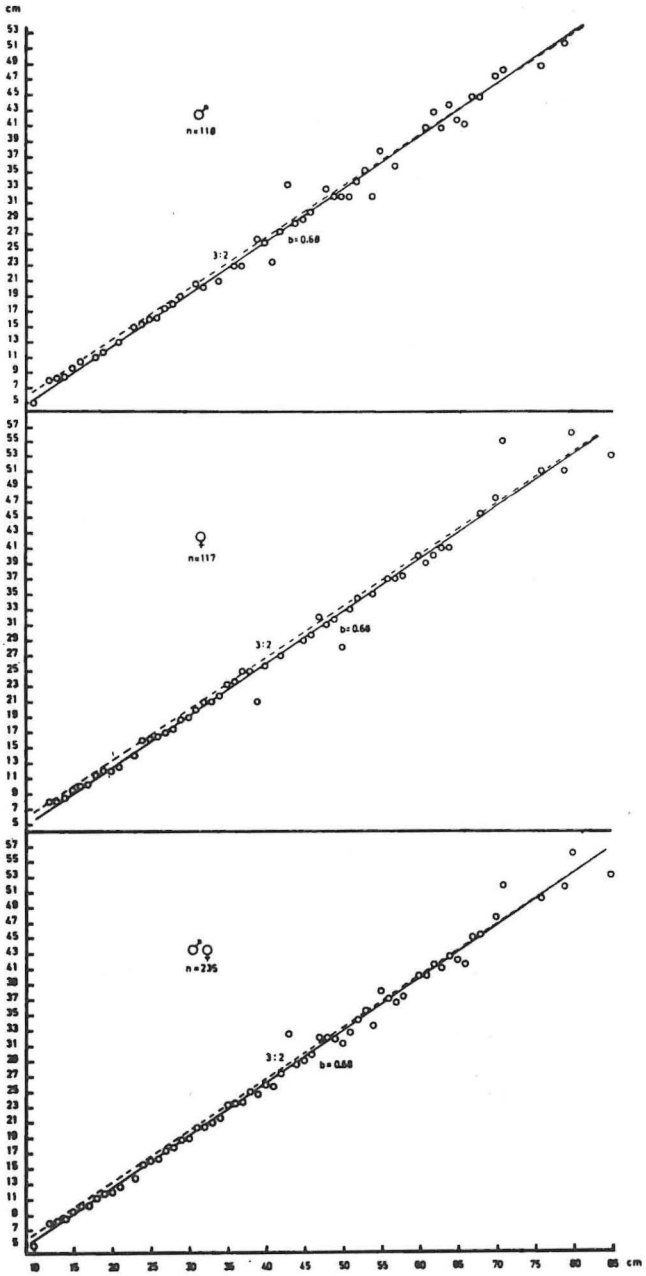

Fig. 4. Ratio of body length and width across the disc in Thornback Ray in the area of the open Central Adriatic

of width of disc $V = 30.6\%$. In males the coefficient of variation of body length is $V = 52.9\%$ and of width of disc $V = 48.8\%$. In both plastic dimensions the females vary more than the males do, i. e. from 1.6—1.8%.

The regression line and the line 1:w = 3:2 coincide well in both sexes. In quite small and immature rays there is a somewhat more considerable deviation from that ratio in relation to the adult samples. In the immature rays the width across the disc, in relation to body length, is somewhat smaller than the ratio 1:w = 3:2 is, which we can find in adult samples. An ideal ratio is fount only in adult males 67—73 cm long and 41.5—48.5 cm across the disc. Moreover, in the largest male samples this ratio is in excess on behalf of the width across the disc. In females, however, the width across the disc in relation to body length is always somewhat smaller than the 3:2 ratio is. It seems that in the lifetime of the Thornback Ray, judging by the dissimilar ratio body length/width of disc, there is a tendency of a more rapid increase in width than in length, which is particularly stressed in males. This various growth of body length and width of disc in the lifetime of the Thornback Ray is shown in Fig. 5. Here the ratio 1:w = 3:2 is replaced by the ratio $R = 1/s = 1.50$, which is taken as the value 0, and the deviation from this ratio corresponds to either + or — of this value.

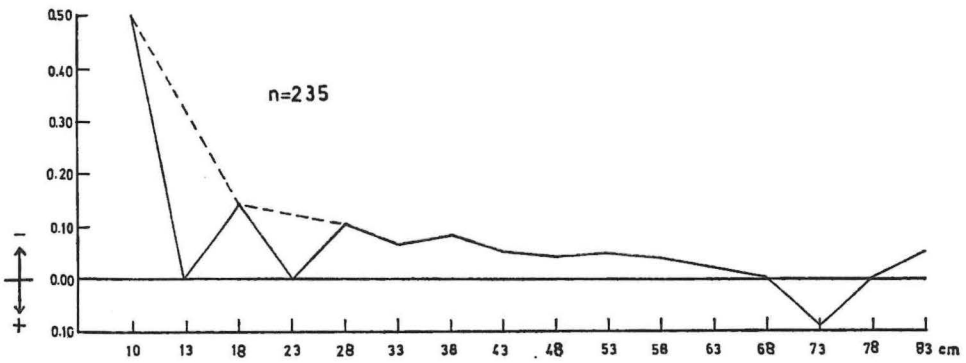

Fig. 5. Difference in the ratio of body length and width of disc in Thornback Ray during growth

The obtained body length and width of disc ratios for the Thornback Ray are identical to the earlier data by Čandjija. On the average the younger samples of the Ray had a smaller width across the disc than the adult ones had in relation to the proportion 1:w = 3:2, while in the largest samples this proportion shifted in favour of the width of disc. The span of deviation from this relation, according to the a/m author, was $V = \pm 0 — 3$ cm. Thus we can conclude here too that the relation of the body length to the width across the disc is like 3:2 $\pm$ V. Its importance is that the width of the Ray can be approximately determined by its length and vice versa. Therefore w = 2/3 l, and l = 3/2 w.

In the channels of the Central Adriatic Županović *(op. cit.)* found that in the male the value $R = 1.58$, and in the female $R = 1.54$, concluding thus that the male has a somewhat smaller width across the disc than the

female has, which would correspond to the fact that the former mature earlier. The obtained values of the proportion R for the region of the open Central Adriatic are close to the values obtained for the channel region of the Central Adriatic.

B l e g v a d *(op. cit.)* quotes for the North Atlantic that the width across the disc in the later stages of the life-cycle is about half the maximal body length. C l a r k *(op cit.)* thinks that in the English Channel the width across the disc is 65—70% of the total body length, while in the Mediterranean (Malta, Naples) it is 63—68%. These last data are close to those obtained for the Adriatic (Ž u p a n o v i ć, *op. cit.)*.

3.1.4. R a t i o o f b o d y l e n g t h a n d w e i g h t (g r o w t h)

To analyse the ratio length/weight the weight means of classes of 5 cm intervals were taken. The analysis of the results showed that the increase in weight, in relation to length growth, followed the law of the exponential increasing curve or the law of complex interest, defined as

$$W = A\,(B^x),$$

or rectified

$$\text{long } W = \log A + (\log B)\, x$$

or

$$Y = \alpha + \beta x,$$

as quoted earlier.

The results of the ratio body length/weight in the Thornback Ray in the area of the open Central Adriatic are shown in Table 3 and Fig. 6.

In both sexes we can distinguish three various phases of growth. The first phase corresponds to the growth of juvenile individua, the second one to adolescents and the third one to adult individua. The decline of the regression line of the rectified data was determined by the regression coefficient, which, for each growth phase in sexes, is as follows:

Females:	Juvenile phase	$b = 7.75$	$r = 0.9580$
	Adolescent phase	$b = 40.50$	$r = 0.9766$
	Adult phase	$b = 95.56$	$r = 0.9852$
Males:	Juvenile phase	$b = 3.31$	$r = 0.9651$
	Adolescent phase	$b = 22.99$	$r = 0.9940$
	Adult phase	$b = 73.35$	$r = 0.9869$
Together:	Juvenile phase	$b = 4.36$	$r = 0.9640$
	Adolescent phase	$b = 40.25$	$r = 0.9516$
	Adult phase	$b = 105.39$	$r = 0.9918$

The regression coefficient in the males is, in relation to the same in the females, in all the phases of growth considerably lower. It also follows that individual phases of life in males and females are of various duration. On the basis of the obtained inflection points it follows that the juvenile phase in males ceases at the length of 29 cm, and in females at about 34 cm. The adolescent phase in males stops at 54 cm, and in females at 73 cm, after which

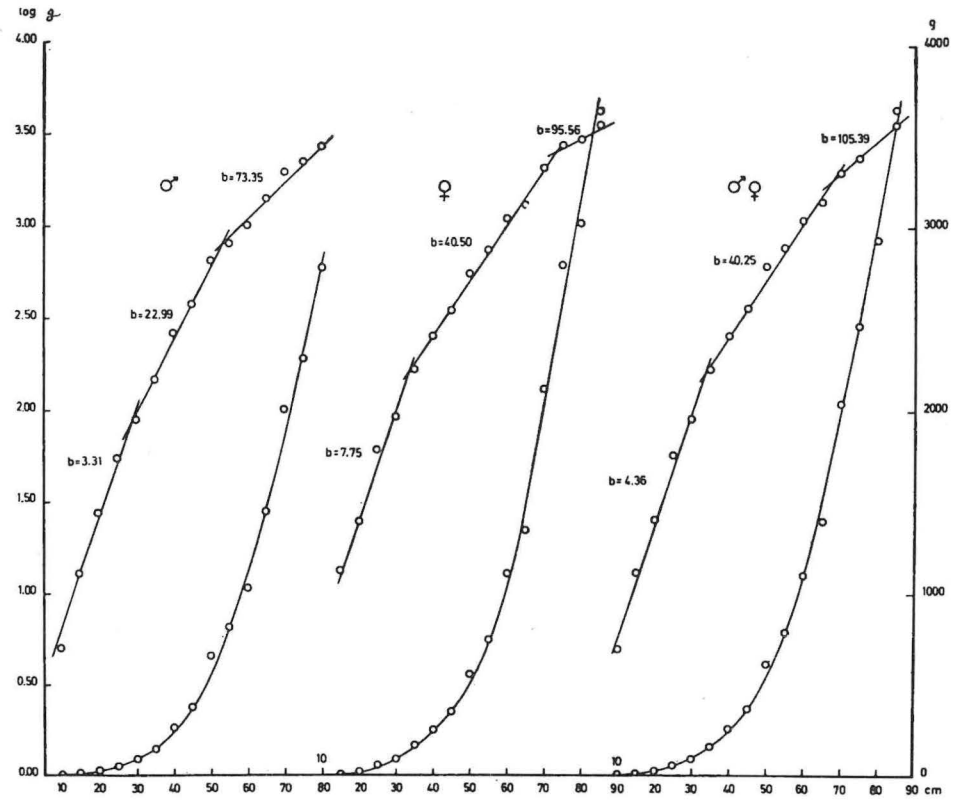

Fig. 6. Ratio of body length and weight of Thornback Ray in the area of the open Central Adriatic (1968—1972)

the adult phase starts. The lengths at which the adolescent phases stop can be considered also as the lengths of the first sexual maurity. The males, as we can conclude, grow more slowly, therefore the males and the females of the same lengths are of different age.

The three various life phases in the Thornback Ray were also found by Županović, *(op. cit.)*. After this writer in the channels of the Central Adriatic sexual maturity of females, starts at the length of from 80—85 cm and width across the disc of from 55—60 cm, and of males at the length of from 55—60 cm and width across the disc beyond 40 cm.

The obtained lengths of the first sexual maturity of the Thornback Ray in the area of the open Central Adriatic are somewhat smaller for females, but they are very close to the lengths obtained for males quoted by Županović for the channel are.

3.1.5. Sex frequency

The numerical ratio males/females in the area of the open Central Adriatic, on the whole, is in balance. There were 290 samples of males captured or 51.8%, and a somewhat smaller number of females, i. e. 271 samples or 48.2%.

The ratio was 1.07:1 on behalf of the males. However, as to the individual length groups the sex ratio varies (Fig. 7, Table 4). The males predominated,

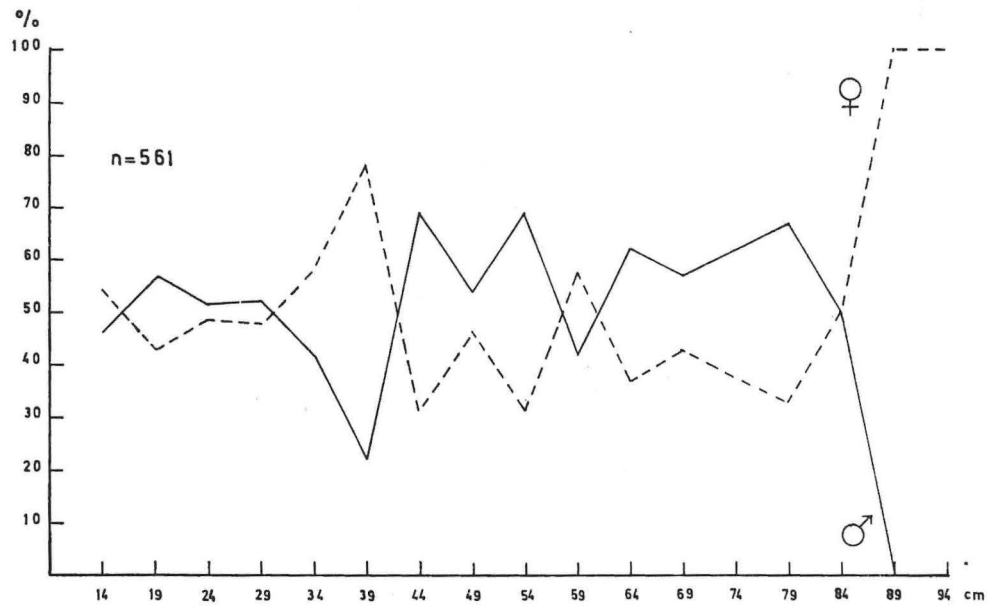

Fig. 7. Sex frequency of Thornback Ray in the area of the open Central Adriatic (1968—1972)

and the females were in excess only at the length of from 34—39 cm, and somewhat less so at the length of 59 cm. A rapid numerical increase of the females, accompained by the simultaneous decrease in the number of the males in the Thornback Ray population occurs beyond 79 cm. All the samples beyond the mentioned length were females exclusively. It seems that the males and females are both in a fairly equal number, perhaps somewhat more males, so that all the variations regarding sex occur later. These variations move from only a few to 100%.

All thorugh the year the sex ratio in the Thornback Ray in the region of the open Central Adriatic is not constant, i. e. it alternates according to season. (Fig. 8, Table 5). A certain preponderance of the males was registred all through the year accompained by a smaller excess of the females in March and September. An exceptionally distinct difference in the numerical ratio of the sexes was registred in January and July. The causes of these very regular annual variations in the sex ratio of the Thornback Ray lies probably in migrations.

In the area of the South Adriatic Kirinčić & Lepetić *(op cit.)* found 155 or 62% of females and 93 or 37.5% of males out of 248 rays, i. e. a ratio on behalf of the females. Čandjija *(op. cit.)* found 314 or 62.8% females and 186 or 37.2% males out of 500 samples caught with long-line, but this ratio was completely reversed in the 1100 samples caught by trawl net,

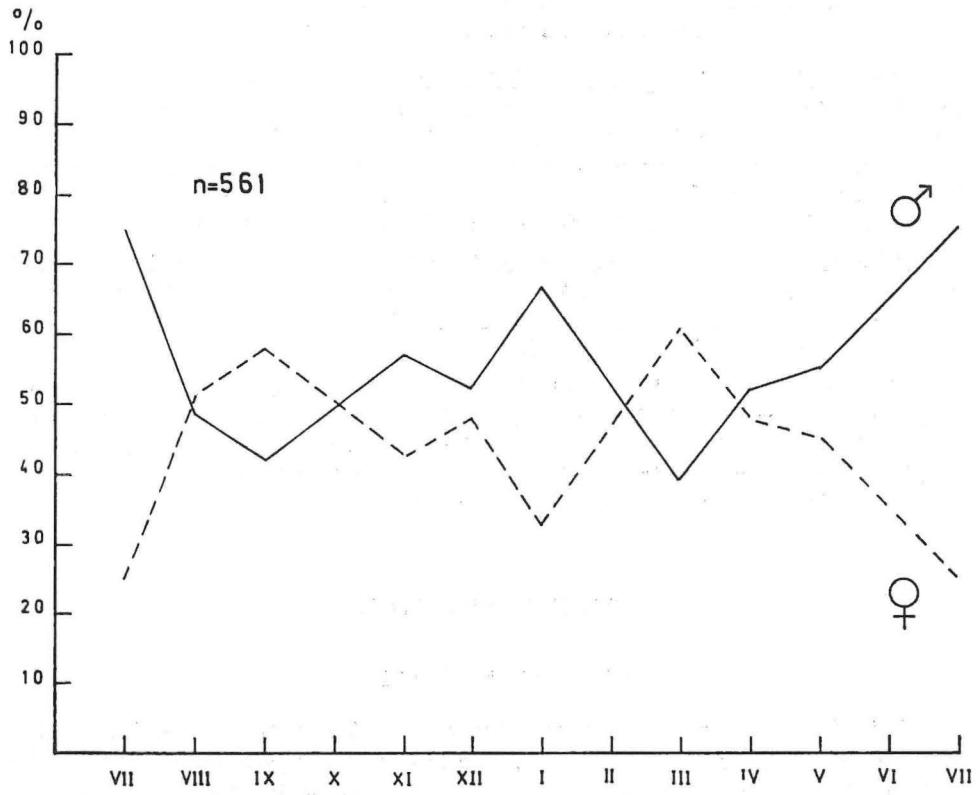

Fig. 8. Sex frequency of Thornback Ray all through the year in the area of the open Central Adriatic

i. e. 562 or 51% males and 538 or 49% females. The sex ratio vas 1.15:1 on behalf of the males, which is very close to the obtained ratio in the area of the open Central Adriatic. Čanadjija noticed that in the catches by long-line the females prevailed, while in those by trawl-net a balanced and probably real sex ratio was obtained. The writer sugests that the greater number of the females were caught with the bait on the long-line because they are probably more wital than the males are, and due to greater metabolism and maturation of sexual products they are in greater need of food. It might be due to the same reasons that there was a considerable difference in the representation of sexes in the results by Kirinčić & Lepetić, since these were obtained by the analysis of the catches by long-line. The sex ratio per length groups, obtained by Čanadjija, completely agree with the ratio obtained for the region of the open Central Adriatic.

Županović *(op. cit.)* in the channels of the Central Adriatic found among 446 Thornback Rays 229 or 51.35% females and 217 or 48.65% males. During the year the sex ratio fluctuated considerably, the males were 6 times in excess the same as the females were.

3.1.6. Sex differences in relation to size in the course of growth

Our results for the open Central Adriatic suggest that the sex differences in relation to body dimensions during the growth of the Thornback Ray could be expressed only in the differences of the tempo of grwth, which would condition various body dimensions in the males and females of the same age. Due to a slow pace of growth in all the phases of life-cycle the males would be somewhat smaller than the females of the same generation.

Kirinčić & Lepetić *(op. cit.)* quote that the females down to 100 m of depth are on an average 2.4 cm larger than the males are. After Županović *(op. cit.)* this difference would be 2.7 cm for body length, and 2.38 cm across the disc on behalf of the females.

This time no such difference in body size between the sexes was observed. The mean values of body length and width across the disc in both sexes were equal. The test of the morphological differences for the body length gave the result $t = 0.15$, and for the width across the disc $t = 0.19$. In both cases the values are far below the value of significance.

3.2. *Raja miraletus* L.

3.2.1. Distribution

Out of 21 stations the Brown Ray was captured only at 4, i. e. at the stations 71, 72, 76, and 94. The greatest number of samples was caught at the station 72, at which the average number of samples in the catches was 10 (Table 1). The distribution of the Brown Ray in the open Central Adriatic is shown in Fig. 9.

The depths at the positive stations were from 111—123 m. The floor at all these stations was sandy with shelly elements (sandy-shelly bottom). After Vatova (Vatova, *op. cit.)* the zoocenosis *Turritella profunda* occurs in this area. The preference of the Brown Ray for these bottoms with a well expressed sandy component is obvious. All the other stations, which lay on muddy bottoms and that did not differ from the a/m ones as to depth and hydrographic characteristics, were negative ones. Therefore the cause of the distribution of this species should be looked for, firstly, in the edaphic factors, and less so in all the others, depths among them.

In the South Adriatic Kirinčić & Lepetić *(op. cit.)* found this species only down to the depth of 100 m. In the channels of the Central Adriatic Županović *(op. cit.)* found this species in the depths of from 80 to 100 m. He also emphasized that not one sample was caught in the Central Adriatic beyond 130 m. With regard to the edaphic factors of distributio he concluded that this species prefers sandy bottoms exclusively. After the data by the »Hvar« cruise (Karlovac, *op. cit.)* it was caught at 50 stations out of the total of 167. The depth span of those stations was from 13—181 m.

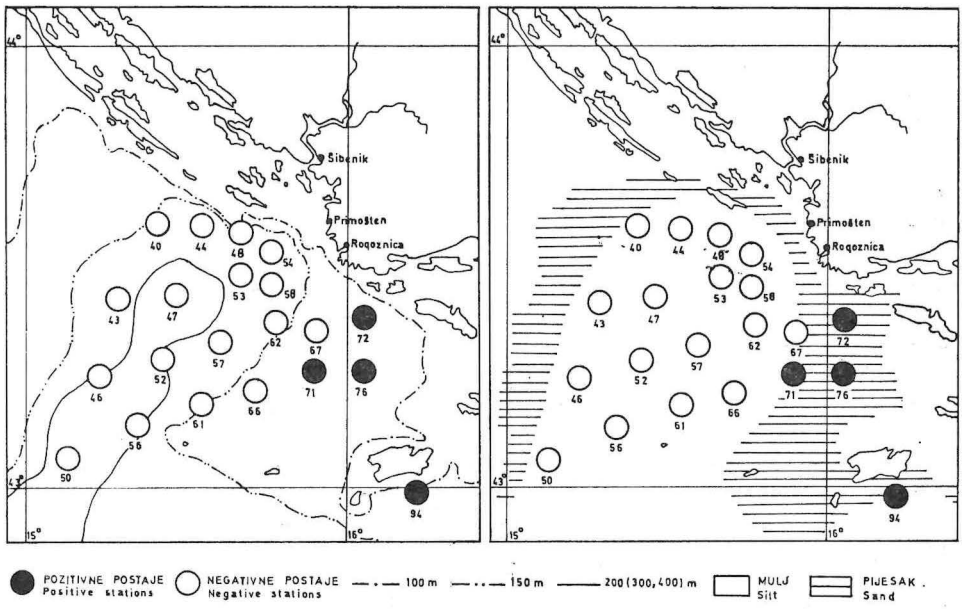

Fig. 9. Distribution o fBrown Ray in the area of the open Central Adriatic with regard to depth and character of bottom

3.2.2. Minimal and maximal dimensions

The longest Brown Ray measured in the area of the open Central Adriatic was 39 cm, with the corresponding width of the disc of 24 cm. The maximal length of the females was 39 cm the width across the disc 24 cm. The longest male sample was 38 cm and 24 cm across the disc. The smallest body dimensions measured were 13.5 cm long and 8 cm across the disc. The mean length of the male was 27.5 cm, with the standard deviation $s = 6.02$, and width of the disc 17.0 cm, with the standard deviation $s = 3.59$. The mean length of the females was 28.0 cm, with the standard deviation $s = 6.55$, and width across the disc. 17.5 cm, with the standard deviation $s = 4.18$. For both sexes the obtained value for length was 27.7 cm, with the standard deviation $s = 6.83$ and width across the disc 17.3 cm, with the standard deviation $s = 3.91$. The mean values of both characters do not show essential differences between sexes.

The population composition of the Brown Ray, with regard to the frequency of individual lengths in the area of the open Central Adriatic is shown in Figure 10.

After Šoljan *(op. cit.)* the Brown Ray in the Adriatic can reach its maximal length of 50 cm. Kirinčić & Lepetić *(op. cit.)* quote 39.2 cm as the maximal length of two females caught in the South Adriatic. Županović *(op. cit.)* quotes the maximal length of 44 cm and 28 cm in width of disc for females, and the maximal length of 42 cm and 25 cm in width of disc for males. The mean values of length for females, the juvenile stages excepted, for the same area were 32.08 cm and 31.09 for males. The mean values for

length of both sexes were 30.75 cm. Grubišić *(op. cit.)* quotes 57 cm as the longest measured Brown Ray in the Adriatic.

Moreau *(op. cit.)* quotes 50 cm as the maximal length of the Brown Ray in the waters of the French coast. For the North Atlantic Blegvad *(op. cit.)* quotes 50 cm as the maximal length. In the Mediterranean Clark

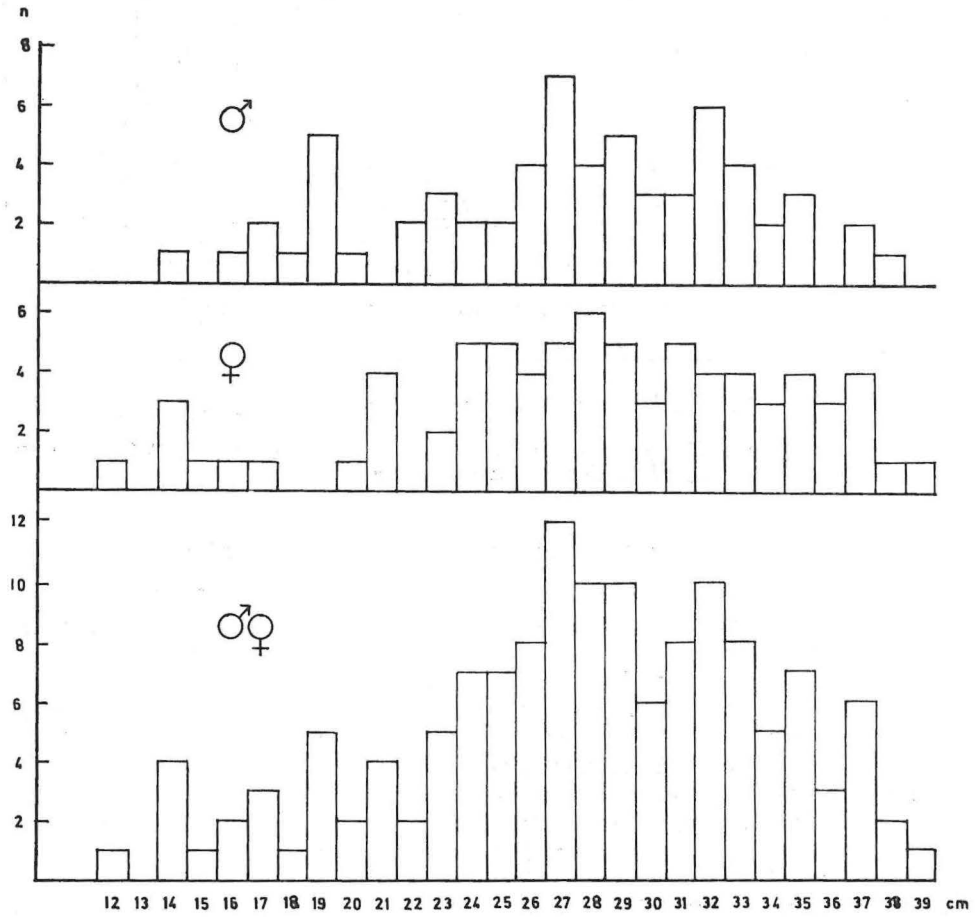

Fig. 10. Frequency of the Brown Ray's length in the area of the open Central Adriatic (1968—1972)

(op. cit.) measured several samples of the Brown Ray. The greatest dimensions for the males were 38.0/24.2 cm and for the females 46.6/28.8 cm.

The maximal lengths of the Brown Ray in the open Central Adriatic are close to the maximal lengths quoted by Kirinčić & Lepetić for the deep South Adriatic, while they are smaller than the maximal dimensions of the Brown Ray obtained for the channel region of the Central Adriatic. As to other seas our data on the maximal dimensions of the Brown Ray are the closest to the data by Clark for the Mediterranean (Malta, Naples).

3.2.3. Ratio of body length and width across the disc

The ratio body length/width across the disc in the Brown Ray is constant in both sexes all through their lifetime (Fig. 11 Table 6). As different from the same ratio in the Thornback Ray, which was 1:w = 3:2, this ratio for both sexes in the Brown Ray is 1:w = 3:1.85. It follows that 1 = 3/1.85 w, and w = 1.85/3 1. As it was mentioned before for each length we can find the corresponding approximate value for width, and vice versa.

For the males the regression coefficient obtained from the ratio body length/width of disc is $b = 0.60$, the correlation coefficient $r = 0.9960$ and the proportion $R = 1.61$. These values for the females were $b = 0.63$, $r = 0.9917$ and $R = 1.60$. For both sexes taken together these values were: $b = 0.62$, $r = 1$ and $R = 1.60$. According to the obtained regression coefficient it follows that in the males per each centimeter of growth in length there is about 0.60 cm in width of disc, and in the females about 0.63 cm. This means that the females grow, on the average, somewhat more in width than the males do.

The values of the coefficient of variation for body length and width of disc show that the females in bogth plastic sizes vary more than the males do. The coefficient of variation for body length in the females was $V = 23.4\%$, and for width of disc $V = 23.9\%$. The values of the coefficient of variation for body length in the males were $V = 21.9\%$, and for width of disc $V = 21.1\%$. The difference in the variety of body length was 1.5% and for width of disc 2.8% on behalf of the females. It is to be noticed that in both plastic characters each sex individually varies rather evenly so that in this sense there is no difference between sexes.

Županović *(op. cit.)* finds for the channel region of the Central Adriatic that the width across the disc is from 62.4—66.1% of the total body length. These values are very close to our values obtained for the channel region of the Central Adriatic, i. e. 61.7%.

Blegvad *(op. cit.)* quotes for the North Atlantic than the width across the disc is from 60—63% of the total body length. Clark *(op. cit.)* gives the relation for the Mediterranean as from 60.8—63.6% The values obtained for the North Atlantic and the Mediterranean are very close to our results for the area of the Central Adriatic.

3.2.4. Ratio of body length and weight (growth)

The analysis of the ratio body length/weight was carried out on 82 samples of Brown Ray. The means of weights of the 3 cm span classes were taken by first rounding the lengths off to whole numbers. The obtained results are given in Table 7 and Figure 12.

The weight increase follows the law of the exponential increasing curve the same as in the previously mentioned species. Thus, growth rate is defined by the formula

$$W = A\ (B^x)$$

In both sexes two growth phases could be distinctly distinguished. The first growth phase, lasting until the length of about 22 cm, probably corresponds to the juvenile phase, and the second one, which lasts from 22 cm to

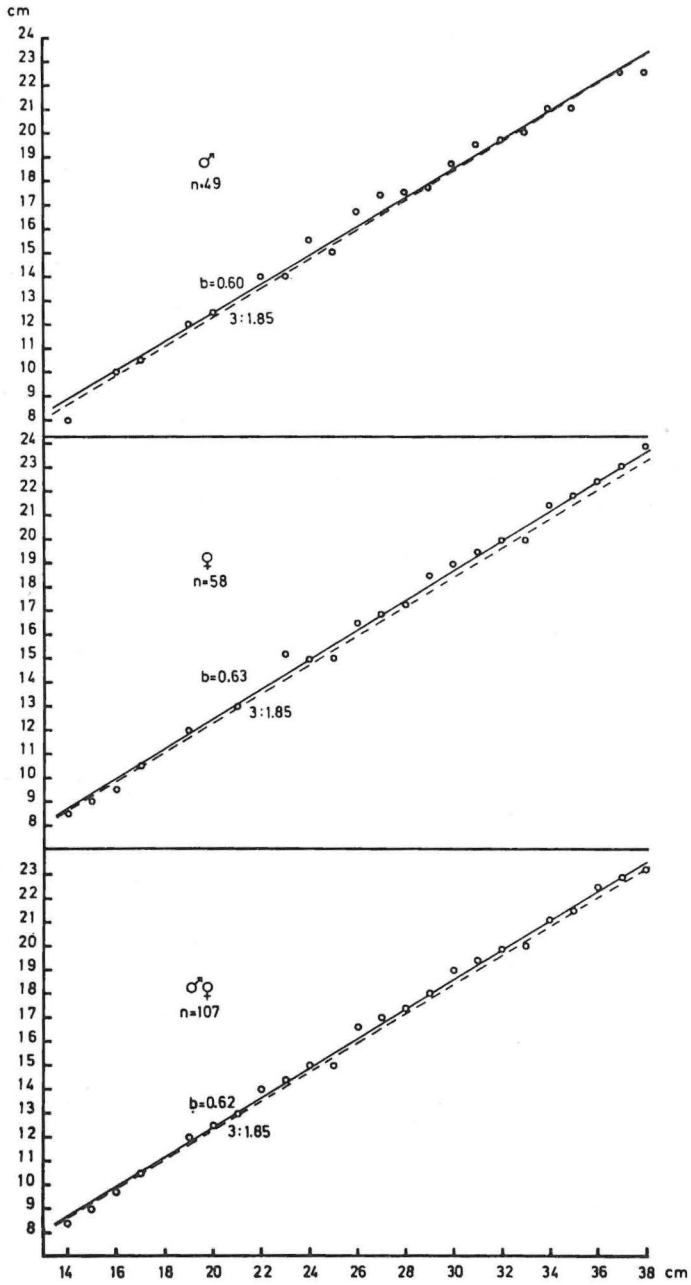

Fig. 11. Ratio of body length and width across the disc in Brown Ray in the area of the open Central Adriatic

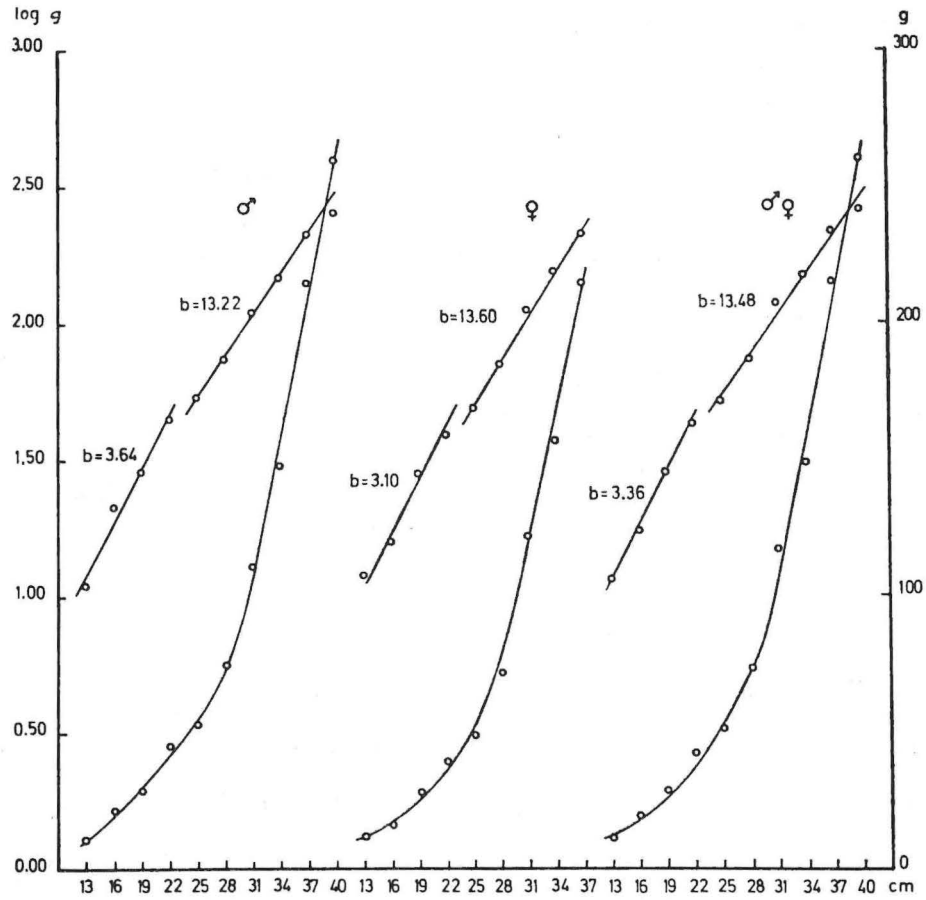

Fig. 12. Ratio of body length and weight of Brown Ray in the area of the open Central Adriatic (1968—1972)

37 cm, to the adolescent phase. The obtained values for the weight in the classes over 37 cm show that it is possible that the inflexion point between the adolescent and adult phases exists, which would mean that in the lengths above 37 cm sexual maturity occurs. In that case the length of about 37 cm would also be the length of the first sexual maturity of the Brown Ray. Županović *(op. cit.)*, for the channels of the Central Adriatic, considers the length of 35 cm as that of the first sexual maturity, since only in the females of that length he could find ovisacs. This length would correspond to the length of the first sexual maturity obtained in this case. The lack of samples of Brown Ray above 37 cm made it impossible to clearly construct the course of the adult life phase.

The obtained regression and correlation coefficients for the two clearly distinguished growth phases were:

Females:	Juvenile phase	$b = 3.10$	$r = 0.9815$
	Adolescent phase	$b = 13.60$	$r = 0.9931$
Males:	Juvenile phase	$b = 3.64$	$r = 0.9870$
	Adolescent phase	$b = 13.22$	$r = 0.9801$
Together:	Juvenile phase	$b = 3.36$	$r = 0.9903$
	Adolescent phase	$b = 13.48$	$r = 0.9841$

It can be seen from the above that the rate of growth in the males in the juvenile phase is somewhat quicker than it is in the females. In this phase the weight increase in the males was 3.64 g per each centimeter of growth, and in the females this was 3.10 g. In the adolescent phase the opposite was the case. Here we can notice a quicker weight increase in the females in relation to the males. The obtained values for the females were 13.60 g/cm, and for the males 13.22 g/cm. In the first phase the males were 14.9% heavier than the females were, and in the second phase it was the females that were 2.8% heavier.

3.2.5 Sex frequency

In the region of the open Central Adriatic, out of 140 captured samples of the Brown Ray, there were 76 or 54.2% females and 64 or 45.8% males. The sex ratio was 1.18:1 on behalf of the females. This predominance of the females is the result of their predominance over the males at almost all the lengths. (Fig. 13, Table 8). The greatest predominance of the females was noticed at the lengths of 14 cm and from 35 cm onwards. Beyond the latter lenght the males were very rare. The only excess of the males was noticed at the length of from 17 to 20 cm. These data coincide well with the data Županović *(op. cit)* for the channel region of the Central Adriatic where also the predominance of the females was noticed. In the total of 98 analysed samples there were 64 or 65.31% of females.

3.2.6 Sex differences in relation to bod y dimensions in the course of growth

It follows from the analysis of the ratio body length/width across the disc of the Brown Ray, in the area of the open Central Adriatic, that the females were on the average 0.5 cm longer and as much wider than the males. The mean values of length in the females were 28 cm, and in the males 27.5 cm. The mean values of the width across the disc were 17.5 cm for females and 17 cm for males. Thence also the difference in the regression coefficient of the ratio length/width, which shows that per each cm of length the females grow 0.03 cm in width, more than do the males. The test of the morphological differences showed, however, that the value $t = 0.40$ for length and $t = 0.67$ for width, i. e. below the limit of significance.

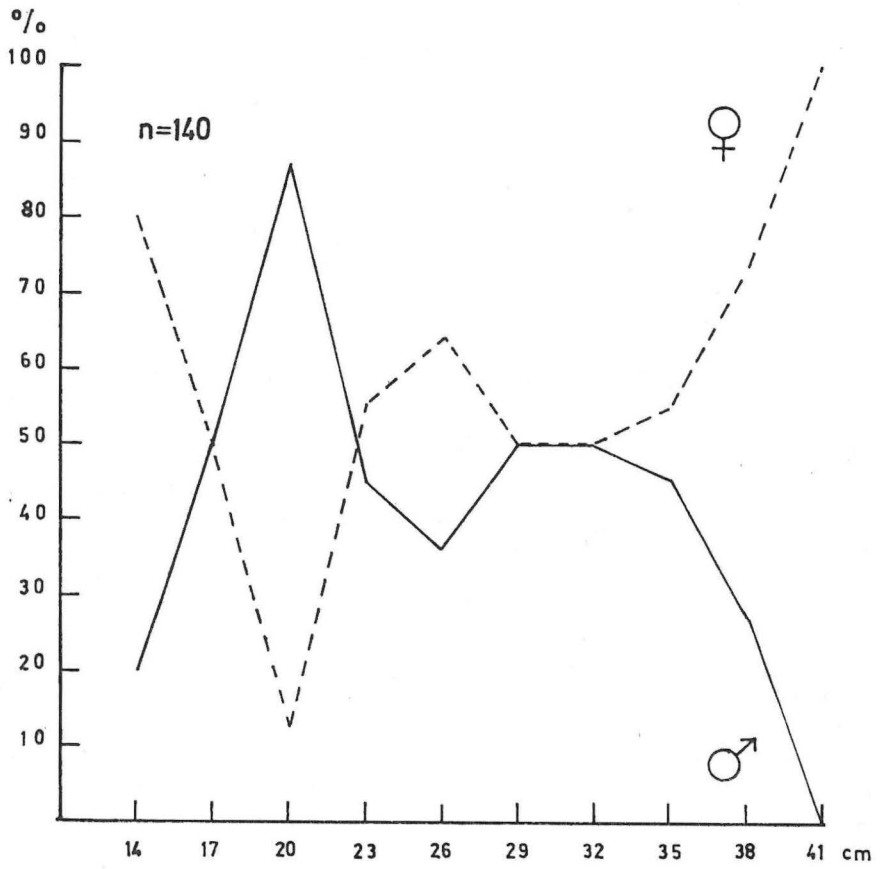

Fig. 13. Sex frequency of Brown Ray in the area of the open Central Adriatic (1968—1972)

Županović *(op. cit.)*, in the channels of the Central Adriatic, found that the maximum mode in the males was 1—2 lower than the mode found in the females.

It seems that the adolescent phase in females lasts somewhat longer than it does in males, which would condition the prolongatoin of growth in females, and therefore the males of the same dimensions as the females would be somewhat older and also lighter. The obtained difference in the regression coefficients corroborates this.

4. DISCUSSION

The researches have shown that some biological problems concerning the Thornback Ray and Brown Ray could be at least partly solved, viz. time (lenght) of the first sexual maturity, maximal body dimensions, sexual

dimorphism and sex ratio in the adult phase of life at the lengths close to the maximal ones. The solution of these problems should be looked for in the peculiarities of and differences in growth of the males and females. From these, and the earlier results (Županović, 1961) three different and clearly separate phases of growth could be noticed in the ratio body length/weight of the Thornback Ray. The first phase would correspond to the juvenile, the second one to the adolescent and the third one to the adult period of life. The regression line of each of these phases is clearly determined by inflexion points, which mark the beginning and end of their duration. The inflexion point between the adolescent and the adult phases of growth of the Brown Ray, and the adult phase itself, here, however, is not quite clear. It can be only guessed in the males from the result of the weight of the length groups above 37 cm, which, in the arith. — log coordinate system, lies considerably below end of the regression line for the adolescent phase and it probably represents the inflexion point, and also the starting point, of the adult phase. The vagueness of the adult phase of the Brown Ray is due to the lack of samples of larger body dimensions, whach made a clear construction of ist beginning and course impossible. The want of samples over 37 cm, which belong to the adult phase (Županović, 1961), is probably the result of intensive fishing, which conditions considerably a rapid decrease both in the number and the average length not only of the adult individua but also of the total stock (Županović, 1963).

The individual phases of life in the sexes differ mutually both in the size of the increase in length and weight and in the lapse of time, which effects certain differences in the body dimensions of the samples of the opposite sex but of the same age, i. e. of the same generation. The growth of the male in both species of Rays is somewhat slower in relation to that of the female in all the observed phases of life. The juvenile phase of life in the male Thornback Ray ends, for example, at the length of 29 cm, and in the female at 34 cm, the adolescent phase in the male ends at 54 cm, and in the female only at 73 cm. Thus, exceptionally great differences in growth occur in the adolescent phase, in which it is also the most rapid. The result of the prolonged growth of the females in the adolescent phase (bearing in mind that the end of the adolescent phase also means a considerable slowing down of further growth) is that the mature males are smaller in size than the sexually mature females of the same age are. The firts sexual maturity of the male Thornback Ray occurs above 54 cm and of the female above 73 cm, which coincides well with the earlier data on the occurrence of the first sexual maturity of this species in the Adriatic (Županović, 1961). This could also be the reply to the question, dealt with also earlier (Čanadjija, 1959), why the fedales predominate in the Thornback Ray (and Brown Ray) exclusively among the samples of larger dimensions. The sugestion mentioned earlier (Čanadjija, 1959) that the cause of this phenomenon should be looked for in the different vitality of the males and females, i. e. the earlier death of the males and therefore their more rapid disappearance from the population, would not be therefore quite correct. Their more rapid disappearance from the population as the result of earlier death would be deceptive. This opinion could be come at only by studying the sex ratio per each length, under the supposition that both sexes grew equally, namely, if they belonged to the same generation, had the same body dimensions. The maximal body dimensions, however, could

be found in females only, and the occurrence of exceptionally large males would be an exception to the rule, thence all the differences noticed in the sex ratio of the larger samples.

The occurrence of dimorphism as the result of uneven growth, though not so well expressed, could be noticed also in the Brown Ray. The first sexual maturity of the females of this species occurs at the dimensions larger than are those of the males, which could be also the result of an uneven growth in the adolescent phase of life. The length of about 37 cm would correspond to the approximate length of the first sexual maturity of the males, according to the earlier mentioned possible point of inflexion for the adult phase. A similar point of inflexion, which would represent the beginning of the adult phase, i. e. the point of the first sexual maturity in the females, was not noticed above 37 cm. It probably occurs somewhat later, although in the cannel region of the Central Adriatic Županović (1961) found females containing ripe ova already at the length of 35 cm, which might be an exception to the general rule.

5. CONCLUSION

By basing it on all the findings regarding the biological and ecological characteristics of the Thornback Ray and the Brown Ray in the area of the open Central Adriatic, we can conclude the following:

Raja clavata L.

1. In the area of the open Central Adriatic the Thornback Ray keeps mainly to the depths down to roughly 160 m, with the maximal population density in the depths of from 100—130 m. It keeps to the muddy and sandy bottoms preferring those with a sandy component. The depth factor seems to be of greater importance, if not the decisive one, for its distribution.

2. The maximal body length and width across the disc of the Thornback Ray in this area was found in the female whose dimensions were 93.0/65.2 cm, and the smallest ones were 10/5 cm. The dimensions of the largest male measured were 79/51 cm. The mean values of body length and width of disc for both sexes were 28.4/23.8 cm, with the standard deviation for length $s = 15.20$ and width $s = 11.85$. The mean values of dimensions in sexes are very close to the previously mentioned ones: 28.2/23.7 cm for the females, with the standard deviation for length $s = 15.38$ cm and width $s = 12.01$, and for the males 28.4/23.9 cm, with the standard deviation for length $s = 15.03$, and width $s = 11.69$.

3. Body length to width across the disc is 3:2. During lifetime a small deviation from this ratio accurs so that the smallest samples are of somewhat smaller, and the largest of somewhat greater width. No difference in this ratio between males and females was noticed. The regression coefficient of this ratio for the females was $b = 0.68$ and for the males $b = 0.68$.

The value for the variability of the width across the disc is smaller than the value for the variability of body length for both sexes, and the females in both plastic sizes vary more than do the males, i. e. from 1.6—1.8%.

4. Three life phases can be distinctly differenciated in this species: juvenile, adolescent and adult. The regression coefficient of the ratio length/weight in the males in all the three phases is considerably lower than is the same ratio in the females. It also follows that the individual life phases in the males and females are of various duration: always longer in the females, which is especially prominent in the adolescent phase in which the growth is most intensive, and therefore the first sexual maturity occurs in the females whose dimensions are larger than are those of the males. The first sexual maturity in the female occurs at 73 cm, and in the males at 54 cm.

5. The sex ratio in the region of the open Central Adriatic was 1.07:1 on behalf of the male. The males most often predominate, and the excess of the females was noticed at the lengths of from 34 to 39 cm and at 59 cm. A rapid increase in the number of females with a simultaneous decrease in the number of males, occurs at the length of 79 cm. In this last phase of increase in the number females their predominance is absolute (100%).

6. The differences in the body dimensions of both sexes during growth spring from the difference in the tempo of growth, the result of which is that the females, due to a prolonged growth in the juvenile and particularly so in the adolescent phase, have larger body dimensions than the males of the same generation have.

Raja miraletus L.

1. The Brown Ray was captured exclusively on sandy bottoms encrusted with shelly elements (sandy-shelly bottoms). The depths of the positive stations were from 111—123 m. It was noticed that this species prefers such bottoms so it seems that the edaphic factor of its distribution is much more important than the depth factor is.

2. The largest body dimensions of this species in the area of the open Central Adriatic were measured on the female, i. e. 39/24 cm. The largest dimensions found in a male were 38/24. The dimensions 13.5/8 cm were the smallest ones in this area. The mean values for body length and width across the disc for both sexes were 27.7/17.3 cm, with the standard deviation for length $s = 6.83$ and for width $s = 3.91$. The mean values of dimensions for the females were 28.0/17.5 cm, with the standard deviation for length $s = 6.55$ and width $s = 4.18$, and for the males 27.5/17.0 with the standard deviation for length $s = 6.02$ and for width $s = 3.59$.

3. The ratio body length/width across the disc is 3:1.85 and is constant for both sexes during lifetime. The regression coefficient of this ratio in the male was $b = 0.60$ and in the female $b = 0.63$ Thus the females grow a little more in width than the males do. In both plastic sizes the females vary more than the males do, i. e. about 2%.

4. In this species, due to shortage of material, it was possible to distinguish only two phases of growth: the juvenile and adolescent, while the adult phase could be only guessed. The juvenile phase in both sexes takes about equal time, while in the adolescent phase certain differences in growth occur. The adolescent phase in the male lasts unitih 37 cm, and in the females most probably until above this length. The length of 37 cm would be the length of the first sexual maturity of the male.

The weight increase in the juvenile phase of the male is somewhat greater than it is in the female, while in the adolescent phase of growth the case is the reverse.

5. The sex ratio in the area of the open Central Adriatic was 1.18:1 on behalf of the female. The greatest predominance of the females was noticed at 14 cm and from 35 cm on. The excess of the males was registered at the lengths of from 17—20 cm.

6. The differences in the body dimensions of both sexes during growth are not well expressed. On an average the females are 0.5 cm longer and wider than the males are. The test of the morphological differences, however, was $t = 0.40$ for length and $t = 0.67$ for width, i. e. below the limit of significance. This difference should be considerably greater, because the females, during the adolescent phase, grow for a longer time and more intensively due to which they are larger and weightier than the males of the same generation are.

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PRILOZI POZNAVANJU BIOLOGIJE I EKOLOGIJE RAŽE KAMENICE (*RAJA CLAVATA* L.) I RAŽE MODROPJEGE (*RAJA MIRALETUS* L.) U JADRANU

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KRATAK SADRŽAJ

I pored dosadašnjih izučavanja biologije i ekologije raže kamenice i raže modropjege u Jadranu (Syrski, 1876; Graeffe, 1888; Kirinčić & Lepetić, 1955; Čanadjija, 1956, 1959; Županović, 1961. a, b; Jardas, 1971. i drugi) biološko-ekološka svojstva ovih vrsta još uvijek su slabo poznata. To se naročito odnosi na njihovu distribuciju, vrijeme i način mriještenja, migracije, fluktuacije, utjecaj intenzivnog izolovanja na gustoću populacije i sl. Pa i druge karakteristike ovih vrsta, koje su češće bile predmetom izučavanja, kao rast, starost, odnos duljine tijela i širine diska, odnos ovih parametara i težine, odnos spolova i sl., nisu dosad potpuno izučene, pa su uzete kao predmet razmatranja u ovom radu.

Materijal za ovaj rad sakupljen je na 21 postaji i 3 lokaliteta na području srednjeg otvorenog Jadrana u razdoblju od 1968—1972. Ukupno je analiziran 561 primjerak *Raja clavata* L. i 141 primjerak *Raja miraletus* L. Materijal su sačinjavali primjerci svih uzrasta.

Obrada materijala vršena je varijaciono statističkim metodama (srednja vrijednost, $\overline{X}$; standardna devijacija, s; koeficijent varijabilnosti, V; standardna pogreška aritmetičke sredine, $s_{\overline{x}}$; vrijednost t; koeficijent korelacije, r; pravolinearna regresija, b i krivolinearna regresija, W).

Dobiveni rezultati za svaku vrstu su slijedeći:

Raja clavata L.

Raža kamenica se na području srednjeg otvorenog Jadrana zadržava uglavnom na dubinama do 160 m sa maksimalnom gustoćom populacija na dubinama od 100—130 m. Zadržava se na muljevitim i pjeskovitim dnima od kojih u većoj mjeri preferira dna sa pjeskovitom komponentom. Faktor dubine je izgleda važniji, ako ne i odlučujući, za njeno rasprostranjenje.

Najveća duljina tijela i širina diska raže kamenice na tom području izmjerena je kod ženke dimenzija 93.0/65,2 cm, a najmanja 10/5 cm. Dimenzije najvećeg izmjerenog mužjaka bile su 79/51 cm. Srednje vrijednosti duljine

tijela i širine diska za oba spola iznosila je 28,4/23.8 cm, sa standardnom devijacijom za duljinu $s = 15,20$, a za širinu $s = 11,85$. Srednje vrijednosti dimenzija kod spolova vrlo su bliske prethodnim, za ženke 28,2/23,7 cm, sa standardnom devijacijom za duljinu $s = 15,38$, a širinu $s = 12,01$ i za mužjake 28,4/23,9 cm, sa standardnom devijacijom za duljinu $s = 15,03$ i za širinu $s = 11,69$.

Duljina tijela naprama širini diska odnosi se kao 3:2. Tokom života dolazi do manjeg odstupanja od tog odnosa tako da su najmanji primjerci nešto manjih, a veći većih širina. Razlika u tom odnosu između mužjaka i ženki nije primjećena. Koeficijent regresije tog odnosa za ženke iznosio je $b = 0,68$, a za mužjake $b = 0,68$.

Vrijednost za varijabilnost širine diska manja je od vrijednosti za varijabilnost duljine tijela, za obala spola, a ženke u obje plastične veličine variraju više od mužjaka za 1,6—1,8%.

Kod ove vrste jasno razlikujemo tri faze života; juvenilnu, adolescentnu i adultnu. Koeficijent regresije odnosa duljine i težine kod mužjaka u sve tri faze znatno je niži od istog kod ženki. Isto tako proizlazi da pojedine faze života kod mužjaka i ženki različito traju; uvijek dulje kod ženki, što naročito dolazi do izražaja u adolescentnoj fazi u kojoj se odvija najintenzivniji rast, pa stoga kod ženki prva spolna zrelost nastupa kod većih dimenzija od onih kod mužjaka. Prva spolna zrelost ženki nastupa kod 73 cm, a mužjaka kod 54 cm.

Odnos spolova na području srednjeg otvorenog Jadrana bio je 1,07:1 u korist mužjaka. Mužjaci uglavnom dominiraju, a eksces ženki zapažen je kod duljina od 34—39 cm i kod 59 cm. Do naglog porasta broja ženki uz istovremeno smanjenje broja mužjaka dolazi kod dužina od 79 cm. U toj posljednjoj fazi porasta broja ženki dolazi do njihove apsolutne dominantnosti (100%).

Morfološka razlika kod spolova temelji se na razlici u tempu rasta, što dovodi do toga da ženke, zbog produljenog rasta u juvenilnoj, a posebno u adolescentnoj fazi, imaju veće tjelesne dimenzije od mužjaka iste generacije.

Raja miraletus L.

Raža modropjega je lovljena isključivo na pjeskovitim dnima koja su najčešće bila inkrustirana ljušturnim elementima (pjeskovito — ljušturna dna). Dubina pozitivnih postaja kretala se od 111—123 m. Zapažena je velika preferentnost ove vrste navedenim danima, pa izgleda da je edafski faktor njenog rasprostranjenja daleko važniji od faktora dubine.

Najveće dimenzije tijela ove vrste na području srednjeg otvorenog Jadrana izmjene su kod ženke sa dimenzijama 39/24 cm. Najveće nađene dimenzije mužjaka iznosile su 38/24 cm. Dimenzije 13,5/8 cm bile su najmanje izmjerene dimenzije na tom području. Srednja vrijednost za duljinu tijela i širinu diska za oba spola iznosila je 27,7/17,3 cm, sa standardnom devijacijom za duljinu $s = 6,83$ i za širinu $s = 3,91$. Srednje vrijednosti dimenzija za ženke bile su 28,0/17,5 cm, sa standardnom devijacijom za duljinu $s = 6,55$ i za širinu $s = 4,18$ a za mužjake 27,5/17,0, sa standardanom devijacijom za duljinu $s = 6,02$ i standardanom devijacijom za širinu $s = 3,59$.

Odnos duljine tijela i širine diska izražen je kao 3:1,85 i stalan je za oba spola tokom cijelog života. Koeficijent regresije tog odnosa kod mužjaka izno-

sio je $b = 0{,}60$, a kod ženki $b = 0{,}63$. Ženke, dakle rastu u širinu nešto više od mužjaka za oko 2%.

Ženke variraju u obje plastične veličine više od mužjaka za oko 2%.

Kod ove vrste, zbog nedovoljnog materijala, bilo je moguće razlikovati dvije faze rasta; juvenilnu i adolescentnu, dok se adultna faza dade samo naslutiti. Juvenilna faza kod oba spola traje podjednako, dok u adolescentnoj fazi dolazi do izvjesnih razlika u rastu. Adolescentna faza kod mužjaka traje do 37 cm, a kod ženki najvjerojatnije do iznad ove duljine. Dužina od 37 cm bila bi dužina prve spolne zrelosti mužjaka.

Težinski prirast u juvenilnoj fazi kod mužjaka nešto je veći od istog kod ženki, dok je u adolescentnoj fazi rasta obrnut slučaj.

Odnos spolova na području srednjeg otvorenog Jadrana bio je 1,18:1 u korist ženki. Najveća dominantnost ženki zapažena je kod 14 cm i idući od 35 cm dalje. Eksces mužjaka zabilježen je kod duljina od 17—20 cm.

Morfološka razlika između spolova nije očita. Ženke su u prosjeku dulje i šire od mužjaka za 0,5 cm. Test morfoloških razlika, međutim, bio je $t = 0{,}40$ za duljinu i $t = 0{,}67$ za širinu, dakle ispod granice signifikantnosti. Ova razlika bi trebala biti znatno veća, budući ženke intenzivnije i dulje rastu tokom adolescentne faze, zbog čega su veće i teže od mužjaka iste generacije.

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Istraživanja su pokazala da barem djelomična rješenja nekih navedenih bioloških problema raže kamenice i raže modropjege, kao npr. vrijeme (duljina) prve spolne zrelosti, maksimalne tjelesne dimenzije (samo ženke dosižu maksimalne tjelesne dimenzije vrste zbog produženog rasta), spolni dimorfizam i odnos spolova u adultnoj fazi života, posebno kod duljina bliskih maksimalnim, leže u osebujnostima i razlikama u rastu i između mužjaka i ženki.

TABLES

Table 1. Survey of stations and localities and average of the Thornback and Brown Ray's catches in the period from 1968 to 1972

Station	Position	Sounding	Bottom	Mean numbere of the specimens per catch	
				Raja clavata L.	*Raja miraletus* L.
40	43°35' N — 15°24' E	181	Clay loam	1	—
43	43°24,5' N — 15°17' E	200—220	Loam	—	—
44	43°35' N — 15°32' E	208—212	Loam	5	—
46	43°14' N — 15°12,5' E	216	Loam	—	—
47	43°25,5' N — 15°27,5' E	199	Loamy clay	—	—
48	43°34' N — 15°39,5' E	188	Clay loam	4	—
50	43°03,5 N — 15°07' E	256	Clay	—	—
52	43°17' N — 15°25' E	186—188	Loamy clay	—	—
53	43°28' N — 15°40' E	176—181	Clay	6	—
54	43°31,5' N — 15°45' E	168	Loamy clay	7	—
56	43°07,5' N — 15°20' E	188—192	Clay loam	—	—
57	43°19' N — 15°35' E	157—160	Loamy clay	—	—
58	43°27' N — 15°46' E	157—165	Loamy clay	13	—
61	43°10,5' N — 15°32,5' E	146—150	Loam	—	—
62	43°22' N — 15°46,5' E	154	Clay	1	—
66	43°12' N — 15°43' E	135—141	Loam	—	—
67	43°21' N — 15°54,5' E	126	Loamy sand	22	—
71	43°15' N — 15°54' E	123	Loamy sand	15	2
72	43°22,5' N — 16°03,5' E	112	Loamy clay sand	10	10
76	43°15,5 N — 16°03' E	111	Clay loam sand	8	4
94	42°58' N — 16°14' E	117—119	Loamy clay	5	7
Mljet	42°40' N — 17°31' E	150	?	9	—
Biševo	42°38' N — 15°55' E	95—100	?	—	—
Biševo	42°34' N — 16°01,5' E	110—115	?	—	—

Table 2. Ratio of body length and width across the disc in Thornback Ray in the area of the open Central Adriatic

	♂♂				♀♀				♂♀			
Lenght (cm)	Number of the specimens	Variation of the width	Mean	1/s	Number of the specimens	Variation of the width	Mean	1/s	Number of the specimens	Variation of the width	Mean	1/s
10	1	5	5	2,00					1	5	5	2,00
12	1	8	8	1,50	2	8	8	1,50	3	8	8	1,50
13	3	8—9	8,3	1,57	3	8	8	1,63	6	8—9	8,2	1,59
14	2	8—9	8,5	16,5	2	8—9	8,5	1,65	4	8—9	8,5	1,65
15	5	9—10	9,6	1,56	6	9—10	9,5	1,58	11	9—10	8,5	1,58
16	2	10—11	10,5	1,52	2	10	10	1,60	4	10—11	10,2	1,57
17					4	10—11	10,2	1,67	4	10—11	10,2	1,67
18	3	11	11	1,64	2	11—12	11,5	1,57	5	11—12	11,2	1,61
19	3	11—12	11,6	1,64	2	12	12	1,58	5	11—12	11,8	1,61
20					1	12	12	1,67	1	12	12	1,67
21	1	13	13	1,62	2	12—13	12,5	1,68	3	12—13	12,7	1,67
23	4	14—16	15	1,53	1	14	14	1,64	5	14—16	14,8	1,55
24	5	15—16	15,4	1,56	3	16	16	1,50	8	15—16	15,6	1,54
25	4	15—17	16	1,56	6	15—17	16,2	1,54	10	15—17	16,1	1,55
26	5	16—17	16,2	1,60	2	16—17	16,5	1,58	7	16—17	16,3	1,60
27	6	17—18	17,5	1,54	2	17	17	1,59	8	17—18	17,4	1,55
28	7	17—19	18	1,56	4	16—19	17,5	1,60	11	16—19	17,8	1,57
29	1	19	19	1,53	5	18—19	18,8	1,54	6	18—19	18,7	1,54
30					1	19	19	1,58	1	19	19	1,58
31	4	20—22	20,7	1,50	3	20	20	1,55	7	20—22	20,4	1,52
32	5	20—21	20,2	1,58	2	21	21	1,52	7	20—21	20,4	1,57
33					2	20—22	21	1,57	2	20—22	21	1,57
34	2	20—22	21	1,62	6	21—23	21,8	1,56	8	20—23	21,6	1,57
35					3	22—26	23,3	1,50	3	22—26	23,3	1,50
36	1	23	23	1,57	3	23—24	23,7	1,52	4	23—24	23,5	1,53
37	2	23	23	1,61	1	25	25	1,48	3	23—25	23,7	1,56
38					1	25	25	1,52	1	25	25	1,52
39	2	26—27	26,5	1,47	1	21	21	1,86	3	21—27	24,7	1,58
40	4	25—27	26	1,54	3	25—27	25,7	1,56	7	25—27	25,9	1,54
41	2	20—27	23,5	1,74	4	26—27	26,7	1,54	6	20—27	25,7	1,60
42	2	27—28	27,5	1,53	1	27	27	1,56	3	27—28	27,3	1,54
43	2	29—38	33,5	1,28					2	29—38	33,5	1,28

44	4	28—29	28,5	1,54					4	28—29	28,5	1,54
45	1	29	29	1,55	1	29	29	1,55	2	29	29	1,55
46	3	30	30	1,53	3	29—30	29,7	1,55	6	29—30	29,8	1,54
47					1	32	32	1,47	1	32	32	1,47
48	1	33	33	1,45	1	31	31	1,55	2	31—33	32	1,50
49	3	31—33	32	1,53	3	31—32	31,7	1,55	6	31—33	31,8	1,54
50	4	32	32	1,56	1	28	28	1,79	5	28—32	31,2	1,60
51	1	32	32	1,59	2	33	33	1,55	3	32—33	32,7	1,56
52	1	34	34	1,53	2	34—35	34,5	1,51	3	34—35	34,3	1,52
53	2	33—38	35,5	1,49					2	33—38	35,5	1,49
54	1	32	32	1,69	1	35	35	1,54	2	32—35	33,5	1,61
55	1	38	38	1,45					1	38	38	1,45
56					2	37	37	1,51	2	37	37	1,51
57	1	36	36	1,58	1	37	37	1,54	2	36—37	36,5	1,56
58					3	37—38	37,3	1,55	3	37—38	37,3	1,55
60					2	38—42	40	1,50	2	38—42	40	1,50
61	1	41	41	1,49	1	39	39	1,56	2	39—41	40	1,53
62	1	43	43	1,44	1	40	40	1,55	2	40—43	41,5	1,49
63	1	41	41	1,54	1	41	41	1,54	2	41	41	1,54
64	1	44	44	1,45	1	41	41	1,56	2	41—44	42,5	1,51
65	1	42	42	1,55					1	42	42	1,55
66	2	41—42	41,5	1,59					2	41—42	41,5	1,59
67	1	45	45	1,49					1	45	45	1,49
68	1	45	45	1,51	2	42—49	45,5	1,49	3	42—49	45,3	1,50
70	3	45—50	47,5	1,47	2	46—49	47,5	1,47	5	45—50	47,6	1,47
71	2	48—49	48,5	1,46	2	53—57	55	1,29	4	48—57	51,7	1,37
76	1	49	49	1,55	1	51	51	1,49	2	49—51	50	1,52
79	1	52	52	1,52	1	51	51	1,55	2	51—52	51,5	1,50
80					1	56	56	1,43	1	56	56	1,43
85					1	53	53	1,60	1	53	53	1,60

Table 3. Ratio of body length and weight in Thornback Ray in the area of the open Central Adriatic in the period from 1968 to 1972

	♂♂			♀♀			♂♀		
Length (cm)	Number of the specimens	Variation of the weight	Mean	Number of the specimens	Variation of the weight	Mean	Number of the specimens	Variation of the weight	Mean
10	1	5	5,00	—	—	—	1	5	5,00
10—15	8	8—16	12,88	12	8—19	13,42	20	8—19	13,20
16—20	5	17—35	27,60	7	18—31	25,00	12	17—35	26,08
21—25	13	20—70	55,38	10	25—90	62,00	23	20—90	58,26
26—30	17	40—135	89,65	14	70—125	93,93	31	40—135	91,58
31—35	9	125—155	147,22	15	105—240	172,87	24	105—240	163,25
36—40	8	190—350	264,38	9	150—290	257,50	17	150—350	260,94
41—45	10	295—440	378,50	6	310—365	355,00	16	295—440	369,69
46—50	8	605—740	662,50	8	430—690	565,00	16	430—740	617,00
51—55	6	605—1090	820,00	5	580—900	757,00	11	580—1090	791,36
56—60	1	1030	1030,00	7	865—1350	1116,43	8	865—1350	1105,63
61—65	4	1050—1830	1446.25	4	1250—1450	1356,25	8	1050—1830	1401,25
66—70	5	1750—2470	2009,00	2	1425—2500	2125,00	7	1425—2500	2042,14
71—75	2	2270—2300	2285,00	2	2800—3800	3300,00	4	2270—3800	2556,67
76—80	2	2390—3175	2782,50	3	2490—3450	3033,33	5	2390—3450	2933,00
81—85	—	—	—	1	3640	3640,00	1	3640	3640,00

Table 4. Sex frequency in Thornback Ray in the area of the open Central Adriatic in the period from 1968 to 1972

Lenght (cm)	Males (No. and %)	Females (No. and %)	Total	Sex ration
10—14	30 (46,1)	35 (53,9)	65	0,85
15—19	60 (56,5)	46 (43,5)	106	1,30
20—24	69 (51,1)	66 (48,9)	135	1,04
25—29	44 (52,4)	40 (47,6)	84	1,10
30—34	17 (41,5)	24 (58,5)	41	0,70
35—39	4 (22,2)	14 (77,8)	18	0,28
40—44	20 (68,9)	9 (31,1)	29	2,22
45—49	13 (54,2)	11 (45,8)	24	1,18
50—54	11 (68,7)	5 (31,3)	16	2,20
55—59	5 (41,6)	7 (58,4)	12	0,71
60—64	5 (62,5)	3 (37,5)	8	1,66
65—69	4 (57,1)	3 (42,9)	7	1,33
70—74	5 (62,5)	3 (37,5)	8	1,66
75—79	2 (66,6)	1 (33,4)	3	2,00
80—84	1 (50,0)	1 (50,0)	2	1,00
85—89	—	1 (100)	1	0
90—94	—	2 (100)	2	0
	290 (51,8)	271 (48,2)	561	1,07

Table 5. Sex frequency of Thornback Ray all through the year in the area of the open Central Adriatic in the period from 1968 to 1972

Month	Males (No. and %)	Females (No. and %)	Total	Sex ration
July	3 (75,0)	1 (35,0)	4	3,00
August	50 (49.0)	52 (51,0)	102	0,96
September	16 (41,0)	23 (59,0)	39	0,69
October	—	—	—	—
November	39 (57,3)	29 (42,7)	68	1,34
December	17 (51,5)	16 (48,5)	33	1,06
January	6 (66,6)	3 (33,4)	9	2,00
February	—	—	—	—
March	23 (39,1)	36 (60,9)	59	0,63
April	66 (51,6)	62 (48,4)	128	1,06
May	39 (54,9)	32 (45,1)	71	1,21
June	—	—	—	—
	259 (51,8)	254 (48,2)	513	1,01

Table 6. Ratio of body length and width across the disc in Brown Ray in the area of the open Central Adriatic

	♂♂				♀♀				♂♀			
Lenght (cm)	Number of the specimens	Variation of the width	Mean	1/s	Number of the specimens	Variation of the width	Mean	1/s	Number of the specimens	Variation of the width	Mean	1/s
14	1	8,0	8,0	1,75	3	8.5	8,5	1,64	4	8,0— 8,5	8,4	1,67
15					1	9,0	9,0	1,66	1	9,0	9,0	1,66
16	1	10,0	10,0	1,60	1	9,5	9,5	1,67	2	9,5—10,0	9,7	1,64
17	2	10,5	10,5	1,62	1	10,5	10,5	1,62	3	10,5	10,5	1,62
19	3	11,5—12,5	12,0	1,57	1	12,0	12,0	1,57	4	11,5—12,5	12,0	1,57
20	1	12,5	12,5	1,60					1	12,5	12,5	1,60
21					3	12,5—13,5	13,0	1,61	3	12,5—13,5	13,0	1,61
22	2	14,0	14,0	1,57					2	14,0	14,0	1,57
23	3	13,5—14,5	14,0	1,64	2	15,0—15,5	15,2	1,51	5	13,5—1,55	14,4	1,59
24	2	15,0—16,0	15,5	1,55	4	15,0	15,0	1,60	6	15,0—16,0	15,2	1,58
25	1	15,0	15,0	1,66	3	14,5—15,5	15,0	1,66	4	14,5—15,5	15,0	1,66
26	2	16,0—17,5	16,7	1,55	1	16,5	16,5	1,57	3	16,0—17,5	16,7	1,56
27	4	17,0—17,5	17,4	1,55	4	16,0—18,0	16,9	1,59	8	16,0—18,0	17,1	1,58
28	2	17,0—18,0	17,5	1,60	3	17,0—18,0	17,5	1,62	5	17,0—18,0	17,4	1,60
29	5	17,0—18,0	17,7	1,63	4	18,0—20,0	18,5	1,56	9	17,0—20,0	18,1	1,60
30	2	18,5—19,0	18,7	1,60	3	18,0—20,0	19,0	1,57	5	18,0—20,0	18,9	1,58
31	2	19,0—20,0	19,5	1,58	4	19,0—20,0	19,5	1,58	6	19,0—20,0	19,4	1,59
32	5	19,0—20,5	19,7	1,62	4	20,0—20,5	20,0	1,60	9	19,0—20,5	19,9	1,60
33	3	19,0—21,0	20,0	1,65	3	20,0	20,0	1,65	6	19,0—21,0	20,0	1,65
34	2	20,0—22,0	21,0	1,61	1	21,5	21,5	1,62	3	20,0—22,0	21,2	1,60
35	3	20,0—22,0	21,0	1,66	4	21,0—22,5	21,9	1,59	7	20,0—22,5	21,5	1,62
36					3	22,5	22,5	1,60	3	22,5	22,5	1,60
37	2	22,0—23,0	22,5	1,64	4	22,5—24,0	23,1	1,60	6	22,0—24,0	22,9	1,61
38	1	22,5	22,5	1,68	1	24,,0	24,0	1,58	2	22,5—24,0	23,2	1,63

Table 7. Ratio of body length and weight in Brown Ray in the area of the open Central Adriatic

	♂♂			♀♀			♂♀		
Lenght (cm)	Number of the specimens	Variation of the weight	Mean	Number of the specimens	Variation of the weiht	Mean	Number of the specimens	Variation of the weight	Mean
Do 13	1	11	11,00	2	11—13	12,00	3	11—13	11,66
14—16	2	20—23	21,50	1	16	16,00	3	16—23	19,66
17—19	4	19—35	28,75	2	22—34	28,00	6	19—35	28,50
20—22	4	38—51	45,00	3	35—47	39,00	7	35—51	42,42
23—25	5	40—65	53,40	8	35—70	49,38	13	35—70	50,92
26—28	7	55—95	75,00	6	55—105	71,67	13	55—105	73,46
29—31	7	80—140	110,71	8	105—150	122,50	15	80—150	117,00
32—34	7	120—170	148,57	5	115—195	157,00	12	115—195	148,75
35—37	3	195—230	215,00	6	190—250	215,83	9	190—250	215,55
38—40	1	260	250,00	—	—	—	1	260	260,00

Table 8. Sex frequency in Brown Ray in the area of the open Central Adriatic in the period from 1968 to 1972

Lenght (cm)	Males (No. and %)	Females (No. and %)	Total	Sex ration
12—14	1 (20,0)	4 (30,0)	5	0,25
15—17	3 (50,0)	3 (50,0)	6	1,00
18—20	7 (87,5)	1 (12,5)	8	7,00
21—23	5 (45,4)	6 (54,6)	11	0,83
24—26	8 (36,0)	14 (64,0)	22	0,57
27—29	16 (50,0)	16 (50,0)	32	1,00
30—32	12 (50,0)	12 (50,0)	24	1,00
33—35	9 (45,0)	11 (55,0)	20	0,81
36—38	3 (27,2)	8 (72,8)	11	0,37
39—41	—	1 (100)	1	0
	64 (45,8)	76 (54,2)	140	0,84