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THE MORPHOMETRY AND POPULATION DIAGNOSIS OF THORNBACK RAY, *RAJA CLAVATA L.*, IN THE ADRIATIC

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1. INTRODUCTION

The Thornback Ray is one of the most numerous cartilaginous fish species in the Adriatic. It is distributed on all kinds of bottoms, with certain preference to sandy ones, down to depth of 200 m. The most numerous population, however, has been found between 100 and 130 m depth.

Šoljan (1948) gives the fundamental diagnosis for the identification of this species in his dichotomic key for determination of the Adriatic fish species. However, besides the description in this determination, particularly few data are available on the mutual relationship among individual body dimensions.

The relationship between body dimensions was dealt with first by Zei (1942) who took into consideration total body length and width of disc. The more detailed considerations of the same body dimensions can be found in the later works by some other authors: Čanadjija (1959), Županović (1961), and Jardas (1973).

Other body proportions and their mutual relationship, important for the diagnosis of this species population, have not been examined in the Adriatic.

2. MATERIAL AND METHODS

The morphological characters of 52 individuals of the Thornback Ray were analysed. The length of males ranged from 13.0 to 76.5 cm and of females from 12.6 to 93.5 cm with greater or lesser discontinuity in the longitudinal frequency. The mean value of length was for males 39.65 cm, and for females 43.09 cm ($X_1 - X_2 = \text{dif.} = 3.44$ cm) whereas for the material as a whole it was 41.57 cm.

The material was collected at different depths in the North, Central and South Adriatic.

The measurements were made of those body proportions which are ordinarily taken in the course of morphometry of this fish group (Clark, 1922, 1926; Bigelow and Schroeder, 1953; Tortonese, 1956; Colignon *et al.*, 1957 and many others). The body dimensions measured are graphically shown in the Fig. 1.

1. Total length (LT) — from the top of rostrum to the end of tail fin.
2. Length of disc (LD) — from the top of rostrum to the line that joins the outermost margins of pectoral fins.

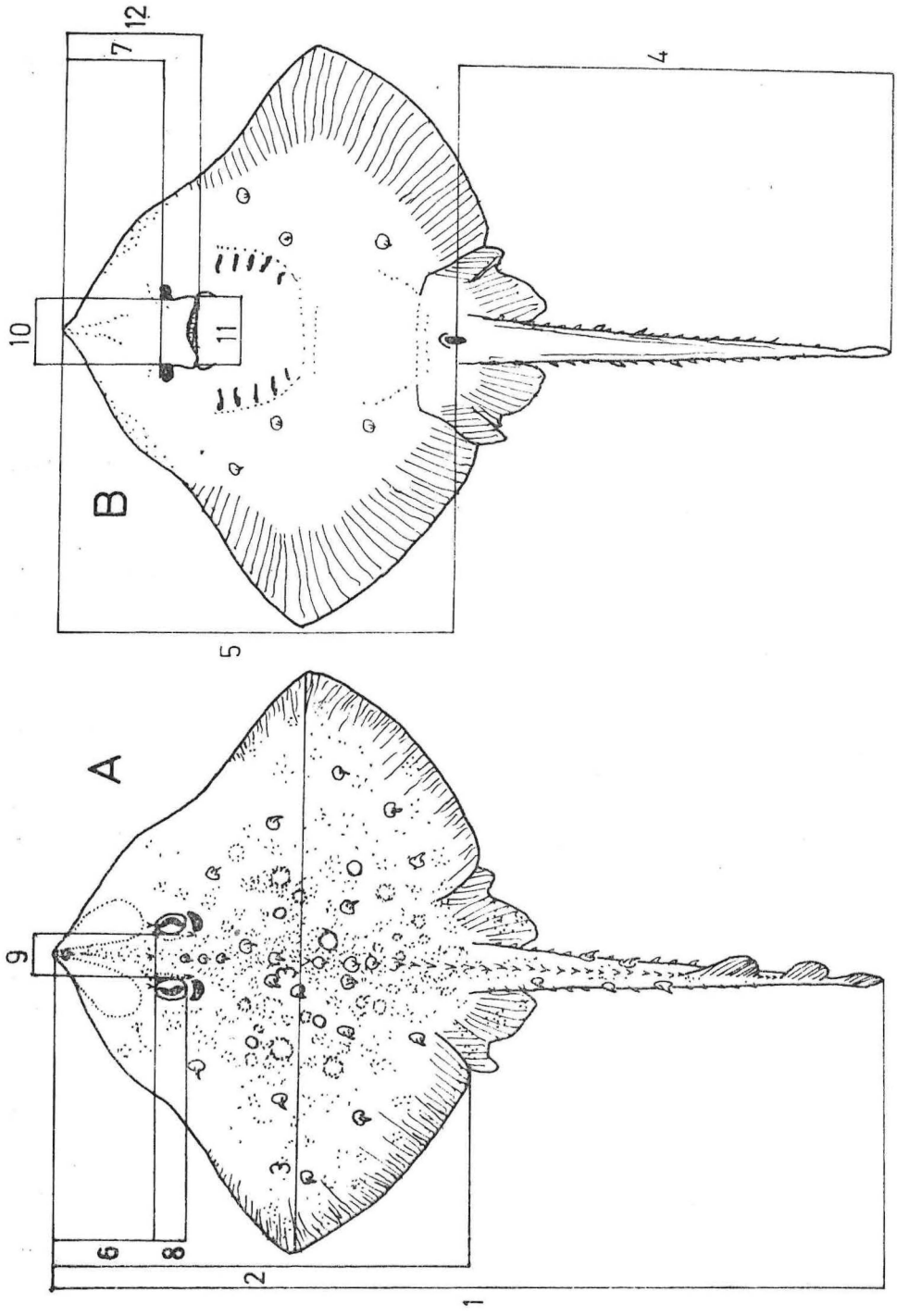


Fig. 1. Schematic outline of the upper (A) and lower (B) side of the body of Thornback Ray with the measured body proportions marks

3. Width of disc (LDs) — the greatest width between the lateral angles of pectoral fins.
4. Length of tail (LC) — from the center of vent to tail end.
5. Praeanal width (PA) — from the top of rostrum to the center of vent.
6. Length of rostrum dorsally (RD) — from the top of rostrum to the line that joins anterior margins of eye holes.
7. Length of rostrum ventrally (RV) — from the top of rostrum to the line that joins the anterior margins of nostrils.
8. Greater eye diameter (O) — the greatest distance from the anterior margin of eye to the posterior one by longitudinal diameter.
9. Interorbital width (IO) — the smallest distance between orbits (bony part).
10. Internasal width (IN) — the smallest distance between internal margins of nostrils.
11. Mouth width (LO) — with mouth shut.
12. Praeoral area (PO) — from the margin of upper jaw to the top of rostrum.
13. Outer angle of disc — angle between the anterior margin of pectoral fin and the posterior one.
14. 1/2 of the anterior angle of disc — after Le Danois (1913), p. 24, fig. 22 and 23.

The measurements of all dimensions were taken from the fresh material. The ventral sides of rays' samples were placed on thick paper and the outline traced. The measurements of length and width of disc and total body length were taken from this tracing. The measurements of other body proportions were estimated over the surface of the fish.

The measures of total body length, length and width of disc, praeanal width and tail length were taken to the nearest cm of 0.1 cm, whereas the measurements of all other body proportions were taken to the nearest mm of 0.1 mm.

The measures of central tendency and variation were calculated applying the variatio-statistical method.

Statistical importance of the difference between the two arithmetical means was obtained calculating the value t:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_{\overline{X}_1 - \overline{X}_2}}$$

$$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}$$

The numerator in the above ratio represents the difference between the arithmetical means, and the denominator the standard error of that difference. The difference between the two arithmetical means is significant if the difference is 1.96, what means 2 times as great as its error, that is to say if the value $t > 1.96$.

3. RESULTS

3.1 Total body length (LT)

The total body length of the specimens analysed ranged from 12.6 to 93.5 cm (Fig. 2). The rays of the total length between 12 and 26 cm were dominant in both sexes, 52.1% in males and 51,7% in females. Another compact group comprised the samples of the total length between 60 and 80 cm. Between these two dominant groups there was no continuity in the material.

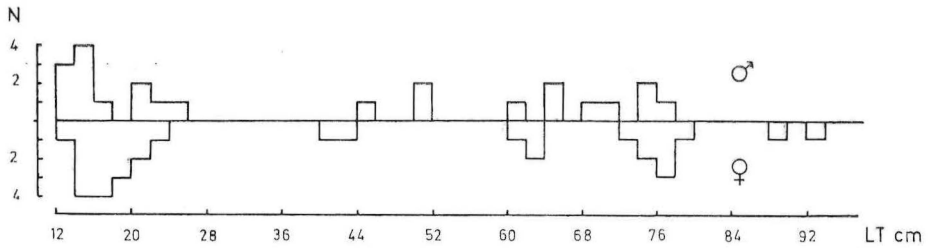


Fig. 2. Frequency of total body lengths of the analysed specimens

The rays with maximal body length were rare. Of the rays captured two females had total length 89.3 and 93.5 cm.

3.2 Length of disc in % of total body length (LD/LT)

The length of disc for males was 47.39% of the total body length, and for females 47.69% (Table 1.). Minimal value for males was 44.44% of the

Table 1.

Sex	Number	$\bar{X} \pm s_x$	t	$\bar{X} \pm s_x$ (♂ + ♀)	V
♂	23	47.39 ± 0.353	0.54	47.45 ± 0.280	3.57
♀	29	47.69 ± 0.422			4.76

total body length, and for females 44.22%, whereas the maximal one was for males 50.85% of the total length, and for females 51.52%. The values for the whole material varied from 44.22% — 51.52% with the mean value 47.45%.

Bimodality was marked in females in this body dimension (Fig. 3) with the modus at 45% and 50%. The modality in males appeared at 47%. The modal values for the whole material were found at 45% and 48%.

The length of disc in the percentages of the total length varied more in females than did in males. The difference was 1.19%.

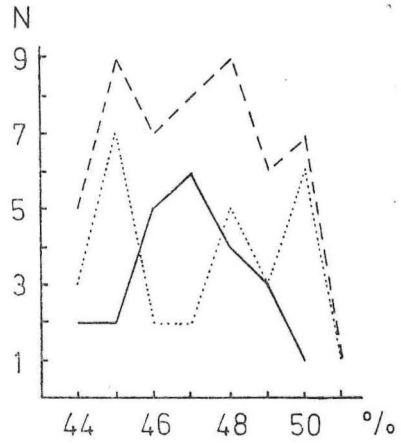


Fig. 3. Length of disc in % of total body length

3.3 Width of disc in % of total length (LDs/LT)

The width of disc was 62.15% of the total body length for males and 63.45% for females (Table 2.). The width of disc in males ranged from 57.96% to 67.32% of the total body length, and in females from 58.16% to 70.99%. The whole material gave following values: range between 57.96% and 70.99%, mean value 62.93%.

Table 2.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	62.15 ± 0.509	1.78	62.93 ± 0.409	3.92
♀	29	63.54 ± 0.596			5.03

Both sexes showed bimodality in this body dimension (Fig. 4.); females at 61% and 64%, and males at 60% and 62% of the total body length with a marked discontinuity. The modalities for the whole material were at 62% and 63%.

In this body dimension females showed variability that was for 1.11% greater than that of males.

3.4 Length of disc in % of width of disc (LD/LDs)

The length of disc was in males 76.27% of the witdh of disc, and in females 75.07%. (Table 3.). In males the value varied from 73.40% to 79.41%, and in females from 72.40% to 78.90% of the width of disc. The values of the whole material were: range from 72.40% to 79.41%, mean value 75.59%. The modal value of this character was, in both sexes, at 76% of the width of disc. (Fig. 5.).

Table 3.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	76.24 ± 0.336	2.60	75.59 ± 0.239	2.11
♀	29	75.04 ± 0.310			2.22

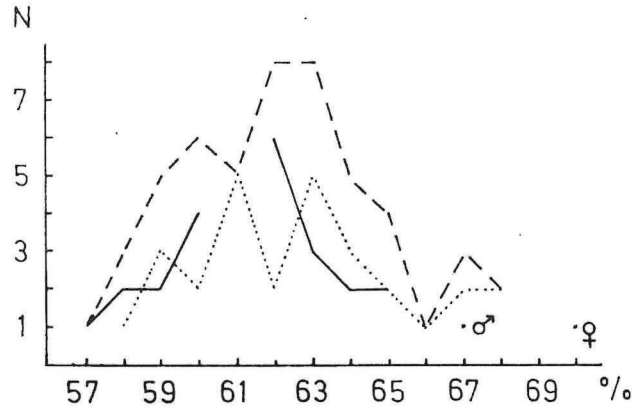


Fig. 4. Width of disc in % of total body length

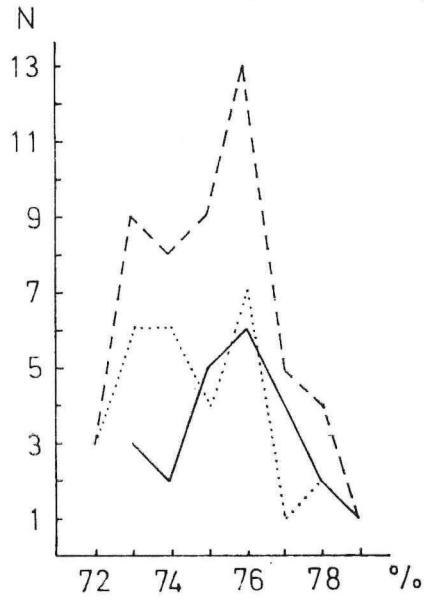


Fig. 5. Length of disc in % of width of disc

The variations in this body dimension were approximately the same for both sexes.

3.5 Praeanal width in % of total body length (PA/LT)

The praeanal width in males was 43.36% of the total body length, and in females 43.84% (Table 4.). The minimal value in males was 36.42%, and in

Table 4.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	43.36 ± 0.445	0.72	43.64 ± 0.344	4.70
♀	29	43.84 ± 0.491			6.14

females 40.12% of the total body length. The maximal value obtained for males was 48.88% and for females 49.01% of the total body length. Values of the whole material were: range 36.42% — 49.01%, mean value 43.64%.

The modal values of males were at 41% and 44%, and of females at 40% — 42% and 46% of the total body length, with discontinuity occurring in both cases. (Fig. 6.).

The variations in this body proportion in females exceeded those in males for 1.44%.

3.6 Length of tail in % of total body length (LC/LT)

The tail length of males was 57.11% of the total body length, and of females 56.15% (Table 5.). The percentages ranged in males from 53.11% to

Table 5.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	57.11 ± 0.534	1.33	56.58 ± 0.367	4.48
♀	29	56.15 ± 0.500			4.79

63.58%, and in females from 50.99% to 59.87% of the total body length.

The modal values for males were at 55% and 58% and for females at 53% and 57% — 59% of the total body length, discontinuity present in both cases. (Fig. 7.). The whole material had the modus at 53% and 58%.

Variations of this character were equally marked in both sexes.

3.7 Length of rostrum dorsally in % of total body length (RD/LT)

The length of rostrum measured on dorsal side was in males 12.72% of the total body length, and in females 12.94%. (Table 6.) The values in males varied from 11.50% to 13.81% and in females from 11.46% to 14.40% of the total body length. The values of the material as a whole were: range between 11.46% and 14.40%, mean value 12.84%.

Table 6.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	12.72 ± 0.115	1.57	12.84 ± 0.086	4.32
♀	29	12.94 ± 0.124			5.18

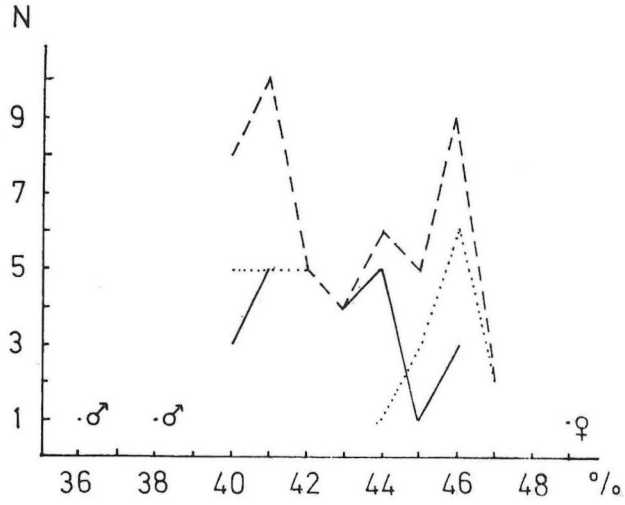


Fig. 6. Praeanal width in % of total body length

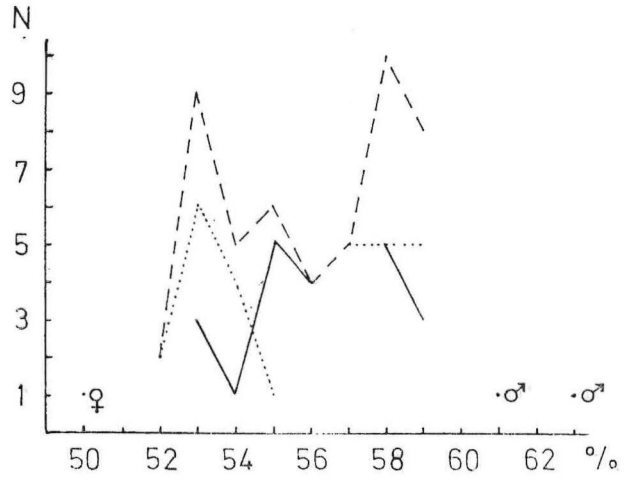


Fig. 7. Tail length in % of total body length

The modal values of this character for both sexes were at 12%. (Fig. 8.).
In females the coefficient of variation in rostrum length was for 0.86% greater than the one in males.

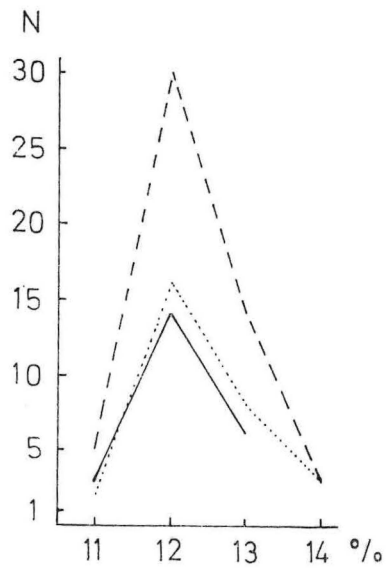
3.8 Length of rostrum ventrally in % of total body length (RV/LT)

The measure of rostrum length taken on ventral side was in males 9.72% of the total body length, and in females 9.85%. (Table 7.) The values of

Table 7.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	9.72 ± 0.119	0.93	9.79 ± 0.080	5.86
♀	29	9.85 ± 0.104			5.69

rostrum length in percentages of the total body length were in males between 8.73% and 10.65%, and in females between 8.42% and 10.81%. The values for the whole material were: range from 8.42% to 10.81%, mean value 9.79%.
The modal value of this character in males was at 9%, and in females at 10% of the total body length. (Fig. 9.).
The variations in the length of the ventral side of rostrum coincided in both sexes.



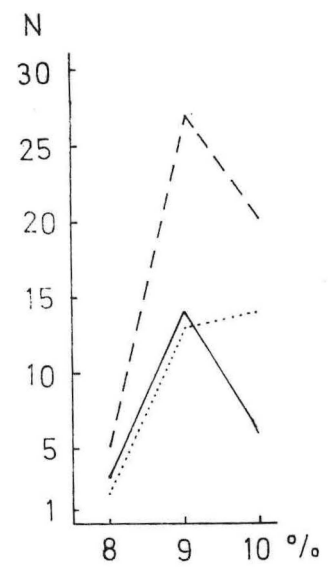


Fig. 8. Length of rostrum dorsally in % of total body length
Fig. 9. Length of rostrum ventrally in % of total body length

3.9 Greater eye diameter in % of total body length (O/LT)

The greater eye diameter was in males 3.63% of the total body length and in females 3.57%. (Table 8.). The minimal values obtained were in males

Table 8.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	3.36 ± 0.083	3.75	3.59 ± 0.065	11.02
♀	29	3.57 ± 0.097			14.52

2.90% and in females 2.55%, whereas the maximal ones in males were 4.35% and in females 4.54% of the total body length. The values obtained for the whole material were: range between 2.55% and 4.54%, mean value 3.59%.

Both sexes showed modality at 3% of the total body length. (Fig. 10.).

Variability in this body proportion was better marked, females varied 3.55% more than males did.

3.10 Interorbital width in % of total body length (IO/LT)

The interorbital width was in males 4.02%, and in females 4.22% of the total body length (Table 9.). In males the values ranged from 3.57% to 4.58%,

Table 9.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	4.02 ± 0.063	1.90	4.13 ± 0.054	7.46
♀	29	4.22 ± 0.082			10.43

and in females from 3.72% to 5.69% of the total body length. The values obtained for the material as a whole were: range from 3.57% to 5.69%, mean value 4.13%.

The modal value of the interorbital width was 3% of the total body length in males, and 4% in females. (Fig. 11.).

The variations of this body dimension were for 2.97% greater in females than were in males.

3.11 Internasal width in % of total body length (IN/LT)

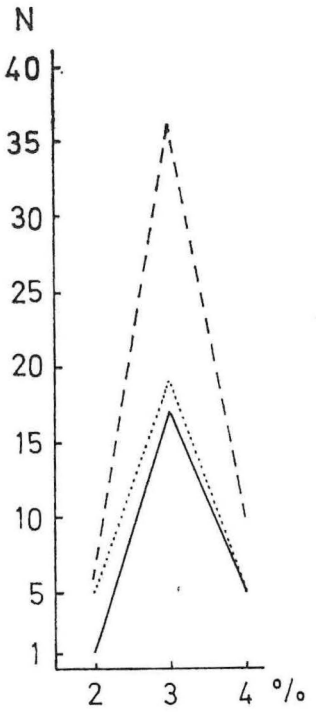
The internasal width was 8.20% of the total body length, with the range from 7.22% to 9.31%. It was in males 8.09, with the range between 7.48% and 8.94%, and in females 8.28%, with the range from 7.72% to 9.31% of the total body length (Table 10.)

The modal value for both sexes was 8% of the total body length. (Fig. 12.)

The values of this body proportion varied more in females than did in males, the difference being 2.79%.

Table 10.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	8.09 ± 0.083	1.31	8.20 ± 0.072	4.94
♀	29	8.28 ± 0.119			7.73



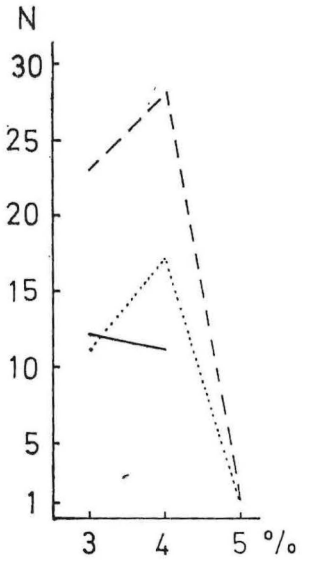


Fig. 10. Greater eye diameter in % of total body length
Fig. 11. Interorbital width in % total body length

3.12 Mouth width in % of total body length (LO/LT)

The mouth width of males was 7.90% of the total body length, and of females 8.03% (Table 11.). The values obtained ranged in males between

Table 11.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	7.90 ± 0.169	0.57	7.98 ± 0.112	10.25
♀	29	8.03 ± 0.152			10.21

6.73% and 9.54%, and in females between 6.75% and 9.38% of the total body length. Out of the whole material following values were obtained: range between 6.73% and 9.54%, mean value 7.98%.

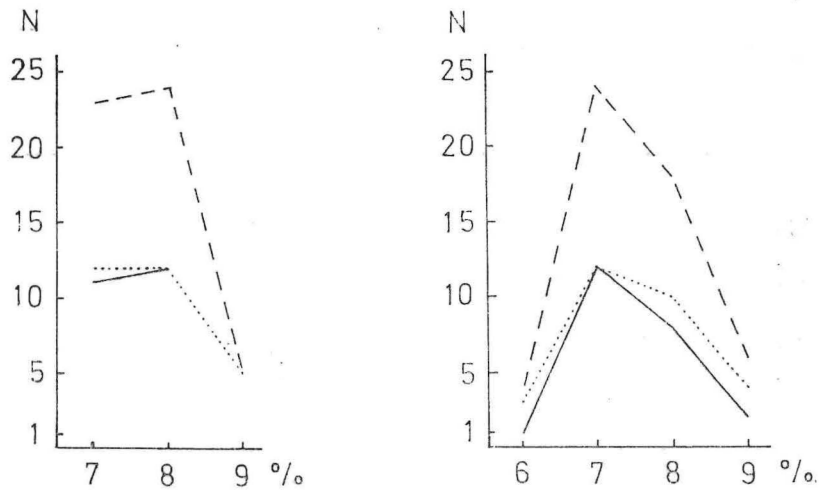


Fig. 12. Internasal width in % of total body length
Fig. 13. Mouth width in % of total body length

The modus showed in both sexes at 7% of the total body length. (Fig. 13.)

A considerable variations of this body dimension showed in both sexes. Variations difference between sexes was not obtained.

3.13 Praeoral area in % of total body length (PO/LT)

The praeoral area of males was 13.62% of the total body length, and of females 13.96% (Table 12.). The values obtained ranged between 11.90% and

Table 12.

Sex	Number	$X \pm s_x$	t	$X \pm s_x$ (♂ + ♀)	V
♂	23	13.62 ± 0.148	1.79	13.81 ± 0.094	5.21
♀	29	13.96 ± 0.119			4.58

14.75% of the total body length in males, and between 12.28% and 15.24% in females. The total values were: range 11.90 — 15.24%, mean value 13.81%.

The modus of males showed at 13%, and that of females at 14% of the total body length. (Fig. 14.)

Variations of this body dimension in males exceeded those in females for. 0.63%.

3.14 Outer angle of disc

The outer angle of disc was mainly uniform in all the individuals measured. This angle, in the majority of cases was 90°, with deviation ±1°.

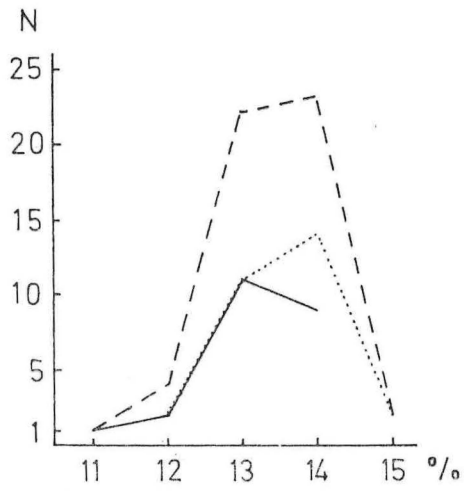


Fig. 14. Praeoral area in % of total body length

3.15 1/2 of anterior angle of disc

In the majority of rays measured, the 1/2 of the anterior angle was 49°. The values obtained ranged within the limits 43°—51°.

3.16 General account of the morphometric analyses results

The results obtained by variatio-statistical method used in working out the morphometric characteristics of the Thornback Ray are listed in the tables 13. and 14. General account of the morphometric analyses of the material as a whole (both sexes) is given in the Table 13., and the account of the results for each sex separately in the Table 14.

Table 13.

Body proportions	Number of samples	Range	$\bar{X} \pm s_{\bar{x}}$	s	V
LD/LT	52	44,22 — 51,52 (7,30)	47,56 ± 0.280	2,02	4,25
LDs/LT	52	57,96 — 70,99 (13,03)	62,93 ± 0,409	2,95	4,68
LD/LDs	52	72,40 — 79,41 (7,01)	75,59 ± 0,239	1,73	2,28
PA/LT	52	36,42 — 49,01 (12,59)	43,64 ± 0,344	2,43	5,57
LC/LT	52	50,99 — 63,58 (12,59)	56,58 ± 0,367	2,65	4,68
RD/LT	52	11,46 — 14,40 (2,94)	12,84 ± 0,086	0,62	4,83
RV/LT	52	8,42 — 10,81 (2,39)	9,79 ± 0,080	0,58	5,92
O/LT	52	2,55 — 4,54 (1,99)	3,59 ± 0,065	0,47	13,09
IO/LT	52	3,73 — 5,69 (2,12)	4,13 ± 0,054	0,39	9,44
IN/LT	52	7,22 — 9,31 (2,09)	8,20 ± 0,072	0,52	6,34
LO/LT	52	6,73 — 9,54 (2,81)	7,98 ± 0,112	0,81	10,15
PO/LT	52	11,90 — 15,24 (3,34)	13,81 ± 0,094	0,68	4,92

Table 14.

Body proportions	Sex	Number of samples	Range	$X \pm s_x$	s	X-diff.	t	V	V-diff.
LD/LT	♂	23	44,44 — 50,85 (6,41)	47,39 ± 0,353	1,69	0,30	0,54	3,57	1,19
	♀	29	44,22 — 51,52 (7,30)	47,69 ± 0,422	2,27			4,76	
LDs/LT	♂	23	57,96 — 67,32 (9,36)	62,15 ± 0,509	2,44	1,39	1,78	3,92	1,11
	♀	29	58,16 — 70,99 (12,83)	63,54 ± 0,595	3,20			5,03	
LD/LDs	♂	23	73,40 — 79,41 (6,01)	76,24 ± 0,336	1,61	1,17	2,60	2,11	0,11
	♀	29	72,40 — 78,90 (6,50)	75,07 ± 0,310	1,67			2,22	
PA/LT	♂	23	36,42 — 46,88 (10,46)	43,36 ± 0,445	2,04	0,48	0,72	4,70	1,44
	♀	29	40,12 — 49,01 (8,89)	43,84 ± 0,499	2,69			6,14	
LC/LT	♂	23	53,11 — 63,58 (10,47)	57,11 ± 0,534	2,56	0,96	1,33	4,48	0,31
	♀	29	50,99 — 59,87 (8,88)	56,15 ± 0,500	2,69			4,79	
RD/LT	♂	23	11,50 — 13,81 (2,31)	12,72 ± 0,115	0,55	0,22	1,57	4,32	0,86
	♀	29	11,46 — 14,40 (2,94)	12,94 ± 0,124	0,67			5,18	
RV/LT	♂	23	8,73 — 10,65 (1,92)	9,72 ± 0,119	0,57	0,13	0,93	5,86	0,17
	♀	29	8,42 — 10,81 (2,39)	9,85 ± 0,104	0,56			5,69	
O/LT	♂	23	2,90 — 4,35 (1,45)	3,63 ± 0,083	0,40	0,06	3,75	11,02	3.55
	♀	29	2,55 — 4,45 (1,99)	3,57 ± 0.097	0,52			14,57	
IO/LT	♂	23	3,57 — 4,58 (1,01)	4,02 ± 0,063	0,30	0,20	1,90	7,46	2,97
	♀	29	3,72 — 5,69 (1,97)	4,22 ± 0,082	0,44			10,43	
IN/LT	♂	23	7,48 — 8,94 (1,46)	8,09 ± 0,083	0,40	0,19	1,31	4,94	2.79
	♀	29	7,22 — 9,31 (2,09)	8,28 ± 0,119	0,64			7,73	
LO/LT	♂	23	6,73 — 9,54 (2,81)	7,90 ± 0,169	0,82	0,13	0.57	10,25	0,04
	♀	29	6,75 — 9,38 (2,63)	8,03 ± 0,152	0,82			10,21	
PO/LT	♂	23	11,90 — 14,75 (2,85)	13,62 ± 0,148	0,71	0,34	1,79	5,21	0,63
	♀	29	12,28 — 15,24 (2,96)	13,96 ± 0,119	0,64			4,58	

Range: As a rule, the range between the minimal and maximal body dimensions, in the percentages of the total body length, was rather limited. Somewhat wider range was obtained only in the width of disc (13.03), praeanal area (12.59), and tail length (12.59).

The difference between the widths of ranges in males and females is obvious. The range in the majority of the body dimensions of females exceeded that of males.

Differences in arithmetical means (X-diff.): Greater differences, slightly above 1%, between the obtained mean values of the measured body dimensions in sexes, were recorded in the width and length of disc. The differences in all the other body proportions were lower.

The obtained values of the arithmetical means in the majority of the body dimensions in females were greater than those in males.

Significance of difference between arithmetical means (t): Statistically significant differences between sexes in the arithmetical means of the measured body dimensions were recorded in the length of disc in percentages of the width of disc ($t = 2.60$), and the greater eye diameter ($t = 3.75$). Statistically significant difference between the above mentioned proportions had the significance at 5% level ($P > 0.05$). The difference between sexes of the arthmetical means in all the other body proportions was not statistically significant.

Coefficient of variation (V): The value of the coefficient of variation was in sexes between 2.11% and 14.57%, and in the whole material between 2.28% and 13.09%. The majority of the body proportions showed greater variability in females than did in males. The differences between sexes in the variations of the measured body proportions ranged from 0.04% to 3.55%.

Modality: Bimodality was noticed in the majority of the analysed body dimensions as characteristic both for sexes and for the material as a whole in length of disc, width of disc, praeanal width, and tail length. However, in length of rostrum ventrally, interorbital width, and praeoral area, only the differences in modalities between sexes occurred.

On the one hand, the causes of bimodality in the mentioned body dimensions are to be found in various relative relations among body dimensions dependent on the difference in growth, and on the other, in the differences between lengths of the same body dimensions in different sexes.

Fig. 15 illustrates the frequency of values, expressed in percentages of the total body length, of those body proportions with bimodality noticed. The values for individuals of both sexes with the total length between 10 and 30 cm, and for those with the total length between 40 cm and 95 cm, are given separately. Difference in modality between these two length groups can be easily seen in the graphical representation. Lower modal values in percentages of the total body length were obtained for praeanal width, length of disc, and width of disc of the rays with the length between 10 and 30 cm. It follows that these body proportions in this fish group are smaller than those in larger individuals.

The opposite ratio was obtained for tail length, greater values obtained for larger individuals. That is why bimodality is not to be considered as a

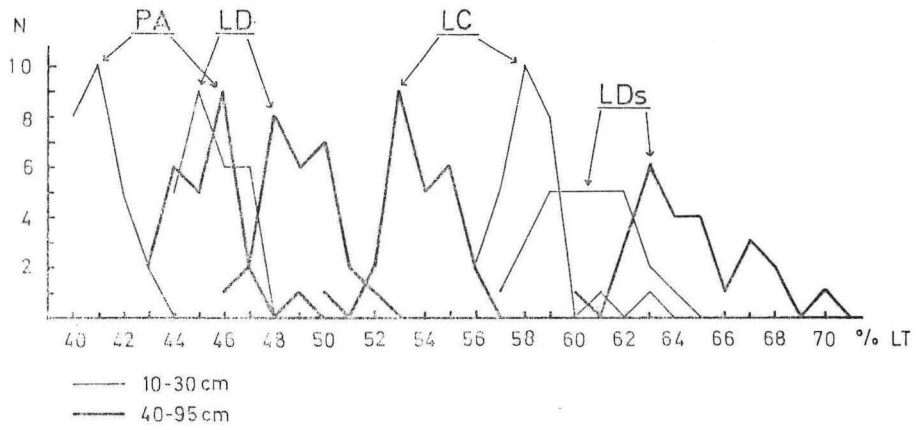


Fig. 15. Frequency of percentage values of body dimensions in relation to total body length

result of morphological differences between the two assumed subpopulations of the Thornback Ray from the different areas in the Adriatic, but as it has been stated aerlier, as a difference in relative growth in the course of life cycle.

4. MORPHOMETRIC DIAGNOSIS OF POPULATION

4.1 Anterior margin and angles

The anterior margin undulated; more in the adult rays than in the juvenile ones (Fig. 16). Outer angle ca 90°. $^1/_2$ of the anterior angle of disc from 43° to 51°.

4.2 Relative ratios of body dimensions

Length of disc 72.4% — 79.4% in width of disc. Length of dorsal side of rostrum (praeorbital area) 4.4 to 5.7 times in width of disc. Interorbital width 2.3 to 3.6 times in length of rostrum dorsally. Length of rostrum ventrally (praenasal area) 5.6 to 7.8 times in width of disc. Internasal area in larger individuals (above 40 cm) is greater for 1/20 of length of rostrum ventrally, whereas in smaller ones is lower to ca 1/3 of length of rostrum ventrally. Praeoral area 6.6 to 8.4 times in total length. Interorbital area is equal to or somewhat lower, to more than $^1/_2$ greater than greater eye diameter.

4.3 Body dimensions in % of total body length

Length of disc 44.2%—51.5%, width of disc 58.0% to 71.0%, praeanal width 36.4%—49.0%, length of tail 51.0%—63.3%, length of dorsal side of rostrum 11.5%—14.4%, length of ventral side of rostrum 8.4%—10.8%, greater eye diameter 2.5%—4.5%, interorbital width 3.6%—5.7%, internasal width 7.2% — 9.3%, mouth width 6.7% — 9.5%, praeoral area 11.9% — 15.2% of the total length.

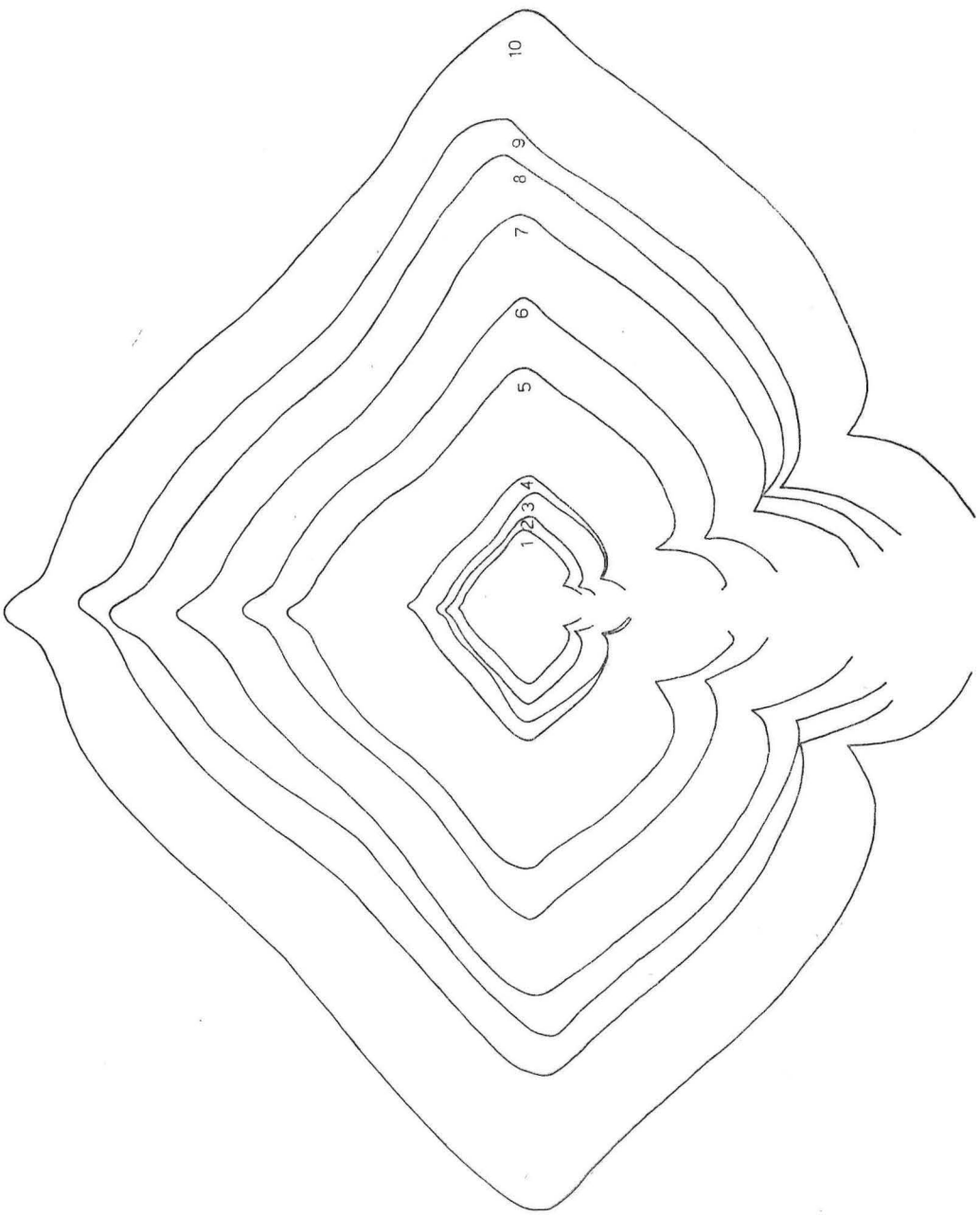


Fig. 16. Disc outlines of samples of Thornback Ray with different body dimensions

1. LDs = 8,1 cm, ♂
2. LDs = 10.0 cm, ♀
3. LDs = 12.3 cm, ♂
4. LDs = 14.2 cm, ♀
5. LDs = 26.7 cm, ♂
6. LDs = 33.2 cm, ♂
7. LDs = 41.8 cm, ♂
8. LDs = 47.1 cm, ♂
9. LDs = 51.3 cm, ♂
10. LDs = 64.5 cm, ♀

5. DISCUSSION

Lengths and mutual relative relations of measured body dimensions of the Thornback Ray vary to a certain extent in dependence of growth. The increase in length and width of disc is proportional to that in the total body length, whereas the relation of the tail length and greater eye diameter to the total body length is somewhat different. In the course of growth these two body dimensions display the linear decrease in length in relation to the increase in the total body length. More intricate relations occur in other body proportions. They spring from the peculiarities of the relative growth of individual body dimensions.

According to the existing data for the Adriatic (Županović, 1961) the width of disc is 63% — 70% of the total body length. These values expressed by the ratio R are for females $R = 1.54$, and for males $R = 1.58$ according to a/m author. Jardas (1973), in the Adriatic, too, obtains the identical ratio; for females $R = 1.56$, for males 1.55, for both sexes taken together $R = 1.54$.

Čanadjija (1959) finds the average mean values of the ratio body length - width of disc to be 3:2 (1:w = 3:2) with variation interval of from 0 to ± 3 cm. A slight deviation from this ratio occurs in the course of growth; younger individuals have smaller width of disc than the adult ones in relation to the proportion 1:w = 3:2. The difference between sexes in this ratio have not been obtained. We can conclude that 1 = 3/2 w and w = 2/3 1. Later on the author (Jardas, 1973) obtains thoroughly identical results for body length and width of disc. The disc width in both sexes shows less variation than does the body length, females vary in both dimensionss 1.6% to 1.8% more than males do. This coincides with the most recent data.

Zei (1942) states that the width of disc increases proportionally in relation to the body length so that larger rays have, on an average, larger disc width. According to the same author the ratio of body length and disc width is, on an average, 1.6 ($R = 1.6$) with the variation span of from 1.2 to 2 and no difference between sexes.

As it can be seen, all the data on the Thornback Ray body dimensions for the Adriatic coincide. The relations between body length and disc width, expressed in percentages ,given in the present account are almost identical to those given earlier by Županović. It is true that the range was obtained with somewhat lower minimal values, but the values given by a/m author coincide to the full with the range of this paper data.

Several characteristic trends were noticed in the more intricate relations between individual body dimensions and the total body length. Besides proportional linear ratios in the disc length, disc width, tail length, and greater eye diameter, lower percentage values were obtained in the internasal width, interorbital width and mouth width for the rays of length below 30 cm. In the length of rostrum ventrally and praeoral width the ratio is completely opposite. On an average the values are greater for the rays of length below 30 cm than for those of greater length. No clear relations between the length of disc and length of rostrum dorsally were attainable. It seems that ratio of quoted body dimensions and body length in invariable for the

individuals of length below 30 cm, whereas for those above 40 cm lengths of mentioned body dimensions decrease in relation to the total body length.

These relations among body dimensions spring from their characteristic increase in the course of growth. In the available material two length groups could be distinguished, the distinction made on the basis of the difference in relationship between the total body length and various body dimensions. The inflexion point between different, and frequently even opposite ratios of body dimensions and total body length occurs in specimens of 40 cm length. This length is the length of the adolescents (Županović, 1961; Jardas, 1973). According to Du Buit (1968), who dealt with the Atlantic rays, the inflexion point between different ratios of the praenasal width, (length of rostrum ventrally), width of disc and the total body length occurs in the individuals above 60 cm length. These body dimensions in the rays below the mentioned length show the tendency of somewhat more rapid growth in relation to the total body length; those above the mentioned length quite the opposite one. This, after the same author, occurs before sexual maturity (75 cm), that is to say, in the adolescent phase.

The appearance of bimodality in the curves of frequency of percentage values within sexes and the material as a whole is due to the existence of the two length groups with, to a certain extent, different relationships among body dimensions (different percentage values in relation to the total body length), that is to say two different groups with different sexual maturity. As it can be inferred from the above this bimodality is not the result of the existence of two subpopulations of the Thornback Ray, with slight morphological differences, but the results of various relative relations in the course of growth, namely in the course of sexual maturation. That is why bimodality cannot be obtained when these body proportions are presented separately by length groups.

When comparing these data to the ones by other authors (Table 15.) all the body proportions coincide, although the data by other authors are incomplete because based on the scarce number of specimens.

Values of disc length in percentages of the total body length given in the present paper show greater values—range with the markedly lowest minimal values in relation to the data by other authors. They come most close to the data for the Mediterranean by Clark (Naples, Valletta). Roland finds out that, in relation to the total body length, disc in juveniles is slightly longer and in adults slightly shorter; this is not in accordance with our data. The value of disc width in percentages of the total body length is nearest to the data by Županović for the Adriatic and by Clark and Roland for the Mediterranean (Naples, Valletta, the coast of Algeria). According to Roland value of the width of disc is higher in relation to the total body length in juvenile individuals than is in adult ones. The largest range of percentage values in relation to the other author's data was obtained in disc width, the minimal values were lower than those given for the Central Adriatic by Županović.

Disc length values in percentages of disc width are, on an average, somewhat higher than those given by Roland for the coast of Algeria.

Dorsal side of rostrum of the Adriatic Ray is 4.4 to 5.7 times in disc width. The data for the Mediterranean by Clark come most close to these ones,

Table 15.

Body dimensions	Author's data	Le Danois (1913)	Clark (1926)*		Dieuzeide *et al.* (1952)	Roland (1952)	Županović (1961)
			1	2			
Lenght of disc in % of total body lenght (LD/LT)	44.2—51.5%		ca 50%	46—49%	ca 50%	48—50%	
Width of disc in % of total body lenght (LDs/LT)	58.0—71.0%		65—70%	63—68%	65—71%	64—70%	63—70%
Lenght of disc in % of width of disc (LD/LDs)	72.4—79.4%					70—75%	
Lenght of rostrum dorsally in width of disc (RD/LDs)	4.4—5.7 times		5.5—6 times	4.8—5.5 times	ca 6 times	5.5—5.7 times	
Interorbital width in lenght of rostrum dorsally (IO/RD)	2.3—3.6 times		2.2—3 times	2.9—3.4 times	ca 3 times	3 times	
Length of rostrum ventrally in width of disc (RV/LDs)	5.6—7.8 times					7.3—8 times	
Internasal area in relation to length of rostrum ventrally (IN/RV)	In larger individuals IN greater for 1/20 RV, and in smaller ones smaller to ca 1/3 RV	IN smaller for 1/4 of length of RV, that is to say IN covers more than 3/4 of length of RV				In smaller individuals IN is smaller for 1/7—1/8 of length of RV, and in adult ones almost the same	
Praeoral area in total body length (PO/LT)	6.6—8.4 times					7.6—8 times	
Interorbital width in relation to greater eye diameter (IO/O)	IO is equal to or smaller to more than 1/2 greater than O		IO is for 1/10 (juveniles) to 1/2 (adults) greater than O				
Outer angle of pectoral fins	ca 90°		ca 90°	ca 90°			
Anterior angle of pectoral fins	43°—51°	52°					

* 1 — The North Atlantic and English Channel
2 — The Mediterranean (Malta — Valetta, Naples)

but as the other author's data are close too, this character shows no marked differences. It has been obtained in this study that length of rostrum dorsally is smaller in relation to disc width in larger rays, whereas in smaller ones the situation is opposite.

The same is with the ratio of interorbital width and dorsal side of rostrum. All the obtained results cover almost the same interval (2.2 — 3.6) i. e. the interorbital width is 2.2 — 3.6 times in length of rostrum ventrally; although in larger individuals the interorbital area is wider in relation to rostrum length.

Roland states that length of rostrum ventrally is 7 to 8 times in disc width. This is, on an average, above the value obtained for the Adriatic Ray. It has been obtained that larger rays have, in relation to disc width, relatively smaller length of ventral side of rostrum than the smaller ones have.

Internasal width in larger individuals is for about 1/20 of the length greater than the ventral side of rostrum is, whereas in smaller ones (below 30 cm) it is frequently shorter for more than 1/3 of rostrum.

Le Danois indicates that internasal area covers more than 3/4 of length of rostrum ventrally. According to Roland the internasal area is slightly smaller in adolescent males; in adolescent females is shorter for $\frac{1}{7}$ to $\frac{1}{8}$, whereas in adult males is of almost identical length to the length of rostrum ventrally. All these data are in agreement with ours.

Praeoral area, according to Roland is 7.6 — 8 times in total body length. Minimal values were ,after a/m author, obtained in immature (adolescent) rays — in males somwehat lower than in females. Maximal values were obtained in adults. We have not noticed that variation in praeoral area depends on the degree of sexual maturity.

Outer angle of disc values are identical for the Adriatic, Mediterranean and Atlantic population of the Thornback Ray.

Anterior angle of disc in the Adriatic Ray differs considerably from the one of the Atlantic Ray. In the Atlantic form this angle is greater to the extent that its value cannot be reached by the extreme maximal values obtained from the Adriatic form measurements.

6. CONCLUSION

1. Specimens of the Thornback Ray of the total body length below 30 cm and above 40 have mutually different body dimensions in relation to the total body length. These dimensions in the smaller individuals are greater or lesser in relation to the same dimensions in the larger ones. This is particularly evident in the length of disc, length of tail, praeoral area and width of disc. That is why bimodality occurs in these body dimensions both within sexes and in the material as a whole.

This bimodality is not the result of the existence of the two morphologically different subpopulations of the Adriatic Thornback Ray, but the result of characteristic relative relations among body dimensions in the course of growth, namely in the course of sexual maturation.

2. Sexual dimorphism is well marked in the length of disc in percentages of width of disc ($t = 2.60$) and greater eye diameter ($t = 3.75$). The differences of arithmetical means did not give statistically significant difference between sexes in other body dimensions.

   The mean values of body dimensions obtained for females are, as a rule, greater than those obtained for males.

3. Variations in body dimensions are not particularly marked. The greatest values of the coefficient of variation were obtained in the greater eye diameter ($V = 3.55\%$), iterorbital width ($V = 2.97\%$) and internasal width ($V = 2.79\%$). The values in all the other body dimensions are somewhat lower or somewhat higher than 1%.

   Greater values of coefficient of variation have been obtained for females in the majority of body dimensions.

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MORFOMETRIJA I DIJAGNOZA POPULACIJE RAŽE KAMENICE, *Raja clavata* L, U JADRANU

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KRATAK SADRŽAJ

U radu se iznose rezultati morfometrijskih analiza populacije raže kamenice, *Raja clavata* L., u Jadranskom moru i na osnovu toga daje se dijagnoza populacije.

Analizom morfometrijskih karaktera obuhvaćena su 52 primjerka oba spola dužinskog raspona od 12.6 — 93,5 cm. Materijal je sakupljen u cijelom Jadranu.

Analizirano je 15 tjelesnih proporcija (Sl. 1) koje se i inače uzimaju kod morfometrijske obrade ove grupe riba. Kod varijaciono-statističke obrade podataka izračunavane su mjere centralne tendencije i varijabilnosti.

Opći pregled rezultata dobiven varijaciono-statističkom obradom morfometrijskih karakteristika dan je u tabelama 13 i 14. U tabeli 13 dan je opći pregled cjelokupnog materijala, a u tabeli 14 pregled morfometrijskih analiza odvojeno po spolovima.

U pravilu širine raspona između minimalnih i maksimalnih vrijednosti mjerenih tjelesnih proporcija u postocima totalne dužine tijela kretale su se unutar uskih granica. Nešto širi raspon dobiven je jedino kod širine diska (13.03), preanalnog prostora (12.59) i dužine repa (12.59).

Evidentna je razlika u širini raspona između spolova. U većini tjelesnih proporcija raspon je bio širi kod ženki nego kod mužjaka.

Veće razlike između dobivenih srednjih vrijednosti mjerenih tjelesnih proporcija kod spolova zabilježene su kod širine i dužine diska, gdje su razlike iznosile nešto više od 1%, dok su u svim ostalim slučajevima razlike bile manje.

U većini tjelesnih proporcija dobivene su veće vrijednosti aritmetičkih sredina kod ženki nego kod mužjaka.

Statistički signifikantne razlike između aritmetičkih sredina mjerenih tjelesnih proporcija kod spolova zabilježene su kod dužine diska u postocima širine diska ($t = 2.60$) i većeg promjera oko ($t = 3.75$). Kod navedenih proporcija dobivena je statički značajna razlika na razini značajnosti od 5% ($P>0,05$). Kod svih ostalih tjelesnih proporcija razlika u aritmetičkim sredinama između spolova nije bila statistički značajna.

Vrijednosti koeficijenta varijabilnosti kod spolova kretale su se unutar granice od 2.11% do 14.57%, a kod ukupnog materijala od 2.28% do 13.09%.

U većini tjelesnih proporcija ženke su varirale više od mužjaka. Razlike u varijabilnosti mjerenih tjelesnih proporcija između spolova bile su od 0.04% do 3.55%.

Kod većine analiziranih tjelesnih proporcija uočena je bimodalnost. Kod dužine diska, širine diska, preanalnog prostora i dužine repa u postotku totalne dužine tijela bimodalnost je bila evidentna kako kod spolova tako i kod ukupnog materijala, dok kod ventralne dužine rostruma, interorbitalnog rastojanja i predusnog prostora postojala je razlika samo u modalitetu između spolova.

Uzroke bimodalnosti kod navedenih tjelesnih proporcija treba tražiti s jedne strane u različitim relativnim odnosima tjelesnih proporcija uvjetovanih različitim uzrastom, a s druge strane u razlikama dužina istih tjelesnih proporcija kod spolova. Na slici 15 prikazana je frekvencija vrijednosti u postocima totalne dužine tijela onih tjelesnih proporcija kod kojih je uočena bimodalnost. Odvojeno su prikazane vrijednosti za primjerke oba spola totalne dužine od 10—30 cm i 40—95 cm. Na grafičkom prikazu jasno se uočuje razlika u modalnosti između tih dviju dužinskih grupa. Kod primjeraka od 10—30 cm u preanalnom prostoru, zatim dužini i širini diska dobivene su niže modalne vrijednosti u postocima totalne dužine tijela, što znači da su te tjelesne dimenzije kod riba ovih dužina manje od istih dimenzija kod većih primjeraka riba. Kod dužine repa dobiven je suprotan odnos; veće vrijednosti dobivene su kod većih primjeraka raže. Stoga bimodalnost ne možemo u ovom slučaju smatrati kao rezultat morfoloških razlika eventualno dviju subpopulacija raže kamenice s različitih područja Jadrana, već kao posljedica razlike u relativnom rastu tokom života.

Na temelju prije iznesenog može se zaključiti da primjerci raže komenice ispod 30 i iznad 40 cm totalne dužine tijela pokazuju međusobno različite odnose tjelesnih dimenzija u odnosu na totalnu dužinu tijela. Kod manjih primjeraka raže tjelesne dimenzije su veće ili pak manje u odnosu na iste dimenzije kod većih primjeraka.

Komparacija morfometrijskih podataka s podacima drugih autora, koja se odnose na druga mora, dana je u tabeli 15.

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