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BIOLOGY AND POPULATION DYNAMICS OF *PAGELLUS ERYTHRINUS* (L.) IN THE INSULAR ZONE OF THE MIDDLE ADRIATIC

BIOLOGIJA I DINAMIKA POPULACIJE *PAGELLUS ERYTHRINUS* (L.) U OBALNOM PODRUČJU SREDNJEG JADRANA

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In this paper the authors dealt with the biology and population dynamics of *Pagellus erythrinus* (L.) in the insular zone of the Middle Adriatic.

Studies carried out were: zoogeographical distribution, length as characteristic of population, length and sexual dimorphism, ratio length-weight, age, growth and mortality.

Data were collected on 10 stations in the insular zone of the Middle Adriatic. Althogether 117 trawling hauls were accomplished from June 1957 through June 1958.

INTRODUCTION

The material providing the basis of this paper was collected from June 1957 of biological investigations. Syrsky (1876) and Graeffe (1888), for example, investigated — among other species — also the reaching of maturity and the spawning season of *Pagellus erythrinus* in the northern Adriatic waters, basing their studies upon the specimens brought to the fishmarket of Trieste. D'ancona (1949) deal with the condition of gonads and sex inversion of this species observed in the Rovinj area. Zei and Županović (1961) studied the sexual cycle and sex reversion of the species in the waters of Istria and Dalmatia. Županović (1961) analyzed the relation between the physical factors and distribution of the species *Pagellus erythrinus* in the sounds of the Middle Adriatic. Rijavec and Županović (1965) dealt with the biology and dynamics of *Pagellus erythrinus* in the Middle Adriatic. Rijavec (1975) studied the biology and population dynamics of *Pagellus erythrinus* in the Bokakotorska and on Montenegrean shelf (South Adriatic).

The results obtained on biology and population dynamics of *Pagellus erythrinus* in the insular zone of the Middle Adriatic are represented in this paper.

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I MATERIAL AND METHODS

The material providing the basis of this paper was collected from June 1957 through June 1958. The location of stations, at which samples were taken in the insular zone of the Middle Adriatic, is shown in Figure 1. (Nos. 1 to 10). The technique of sample taking was identical for each station, and each trawl haul lasted exactly one hour. While all the netted specimens were analyzed when the catches were less abundant, only representative samples were taken with abundant catches. The examinations of analyzed specimens involced the length and weight of their body, their sex and stage of sexual maturity. The age of the individuals was determined from their scales. The scales were taken from two diferent places situated below the »lateral line«, one of them being near the head and the other near the tail. Before the age of the individuals was determined, the scales had been left in distilled water for one day, whereupon they were well cleaned. The scales were observed in water through the binocular as we have learnt through experience that the age determination from scales is much easier and clearer if performed in this way than if the scales are mounted on a glass slide. We did mount them, however, in order to photograph them, using a glass slide and organic paste (54% albumen, 45% glycerin, and 1% natrium silicium).

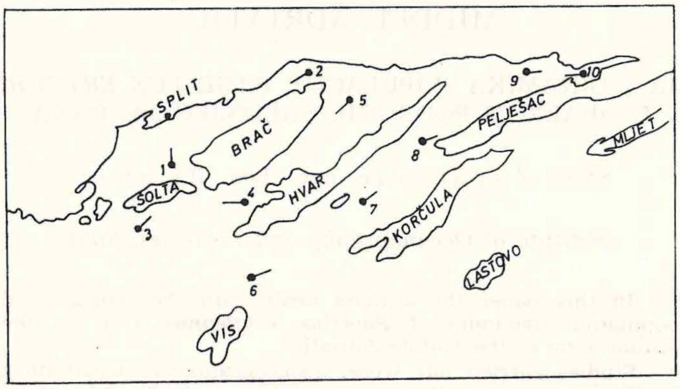

Figure 1. Insular zone of the Middle Adriatic. Trawling stations (—).

In addition to the arithmetical mean and the standard error, calculated by the usual methods, regression was also calculated.

A home-made type of (cotton) net was used, the main dimensions of which were the following:

Length of wings	6.27 m	Mesh size	57 mm
Distance between the wings and the cod end	15.00	Mesh size	27—14 mm
Length of cod end	3.00	Mesh size	14—13 mm

II RESULTS AND INTERPRETATION

A. Zoogeographical Distribution

By surveying our data, and the data resulting from the HVAR Expedition in 1948/49 (Karlovac, 1959), shown in Figure 2, we can obtain a rather distinct idea of the distribution of the species *Pagellus erythrinus* in the Middle Adriatic. As we can see in Figure 2, the distribution of this species

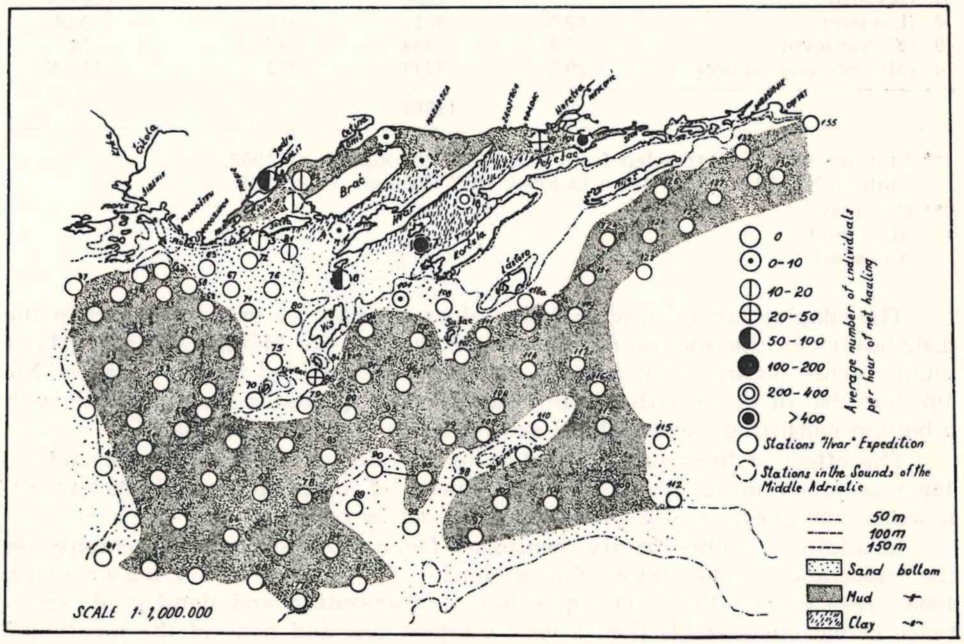

Figure 2. Average number of individuals per hour of net hauling.

in the Middle Adriatic is strictly limited by the 100 m isobath. According to the obtained data, *Pagellus erhthrinus* seems to be a typical species of the circalittoral zone. The number samples from which the average catch values were calculated for the stations in the insular zone of the Middle Adriatic was 12, with the exception of the Station No. 10, where the average catch value was calculated from 9 samples. As to the other stations in the Middle Adriatic area where the species *Pagellus erythrinus* occurred, either during the HVAR Expedition or resulting from our analyzes covering the open part of the Middle Adriatic from 1958 through 1963, the average catch values were calculated from the following number of samples.

Station No. 81	2 samples
Station No. 82	6 ,,
Station No. 83	4 ,,
Station No. 86	3 ,,
Station No. 101	3 ,,

Table I

Station No.	Depth (m)	Number of individuals	Relative number**	Qualitiy of bottom***
1. (Split Sound)	58	184	15	M
2. (Vrulja)	76.5	22	2	M
3. (Maslinica)	104	178	15	CMS
4. (Kabal)	85	80	7	M+SM+CMS
5. (Sumartin)	68.5	94	8	C
6. (Pakleni otoci)	85.5	1133	94	S
7. (Šćedro)	72	1896	158	CS+S
8. (Lovište)	62.5	3812	318	CMS
9. (Kardeljevo)	37.5	554	46	M
10. (Malostonsko more)	29.5	3733	415	M+S
		11686		

** Stations Nos. 1—9 trawled from June 1957 through June 1958.
Station No. 10 trawled from October 1957 through June 1958.

*** C = clay
M = mud
S = sand

The edaphic factor, most probably, does not play an important part in the distribution of the species *Pagellus erythrinus* in the Middle Adriatic. Maximum catches occurred not only in the areas with a mud bottom (Station No. 10), but also in those with a loamy sand bottom (Stations No. 7, 8), and with a bottom consisting exclusively of sand (Station No. 6). See Table I.

The effect of hydrographic factors on the size of catches (Županović, 1961) is much more evident. In the course of investigation of that effect, howecer, the question of exploitation must not be overlooked.

In addition to the already mentioned factors, the authors also emphasizes the importance of the factor of nourishment (Rijavec and Županović, 1965; Rijavec, 1975). The question of distribution and density of occurrence in various areas is then a very complex one and none of the mentioned factors, with the exception of the depth factor, can be considered too narrowly.

B. Biometric analysis

1. Length as characteristic of population

During the period between June 1957 and June 1958 the body length of 4,589 individuals was measured. The total length, i.e. the interspace between the tip of the mandible and the tail fins drawn together, was employed. All the individuals were measured with millimetric precision. The individuals measured in this way can be arranged within the length interval of from 4.0 to 28.0 centimetres. The average body length of the complete population was 14.76 ± 1.26 centimetres. By comparing the average body lengths as resulting for individual stations (Table II), considerable diversity is found.

The analysis of the above data shows that there is no regularity in the distribution of average body lengths according to locality or to population abundance respectively. The minimum average value of the body length (8

Table II

Station No.	Number of individuals	Number of analyzed individuals	Average lenght (cm)
1	184	184	14.14
2	22	22	8.00
3	178	178	17.67
4	80	80	16.23
5	94	93	14.05
6	1133	666	13.93
7	1896	1065	13.93
8	3812	1207	14.96
9	554	501	16.16
10	3733	593	15.12
Total	11686	4589	

centrimetres), for example, was found at Station No. 2, situated near the mainland, where the smallest number of individuals was caught, while the maximum average value of body length (17.67 cm) was found at Statine No. 3, situated at some distance from the mainland, which ranked seventh as regards the number of caught individuahs. The stations Nos. 6 and 7, which are situated still farther from the mainland, present the reverse picturre, with an abundant occurrence of the species *Pagellus erythrinus.* The average body lenth found at those stations was very small (13.93 cm), while the Mali Ston area, situated in the close vicinity of the mainland (Station No. 10), yielded the maximum catch size and the average value of body length (15.12 cm) ranking fourth as regards the number of caught individuals. This irregulerity of body length values could perhaps be explained by the existing seasonal migrations within one and the same population of the species *Pagellus erythrinus* in the Middle Adriatic sound area (Županović, 1961).

The shifting of the *Pagellus erythrinus* population from the shallow waters of the Middle Adriatic sound area to the deeper ones, and vice versa, must inevitably affect also the qualitative changes of the body length of individuals in various months (Table III).

Table III

Date	Number of analyzed individuals	Lenght of interval (cm)	$\bar{x} \pm S_{\bar{x}}$ (cm)
26. VI—1. VII/1957	362	6.0—23.0	14.96±0.12
25. VII—29. VII	308	4.0—20.0	14.07±0.13
2. IX—8. IX	323	7.0—25.0	14.99±0.15
6. X—9. X	449	6.0—28.0	14.56±0.14
6.XI—13. XI	367	4.0—26.0	14.76±0.16
7. XII—10. XII	440	4.0—25.0	15.00±0.15
7. I—11. I/1958.	471	4.0—22.0	14.68±0.13
4. II—7. II	463	5.0—24.0	13.66±0.13
28. II—5. III	170	6.0—26.0	16.45±0.28
1. IV—3. IV	153	4.0—24.0	14.65±0.35
5. V—9. V	381	4.0—28.0	14.75±0.19
4. VI—7. VI	702	5.0—25.0	14.76±0.10
	4589		

The fluctuation of the dominant modus of length frequencies in various months helps us follow the population dynamics. The dominant modus of 13.0 centimetres, for example, applies to July, September, and October; the dominant modus of 14.0 centimetres applies to August, December, February, May, and June; the dominant modus of 15.0 centimetres applies to November and January; while the dominant modus of 16.0 centimetres applies do March and April (Figure 3.).

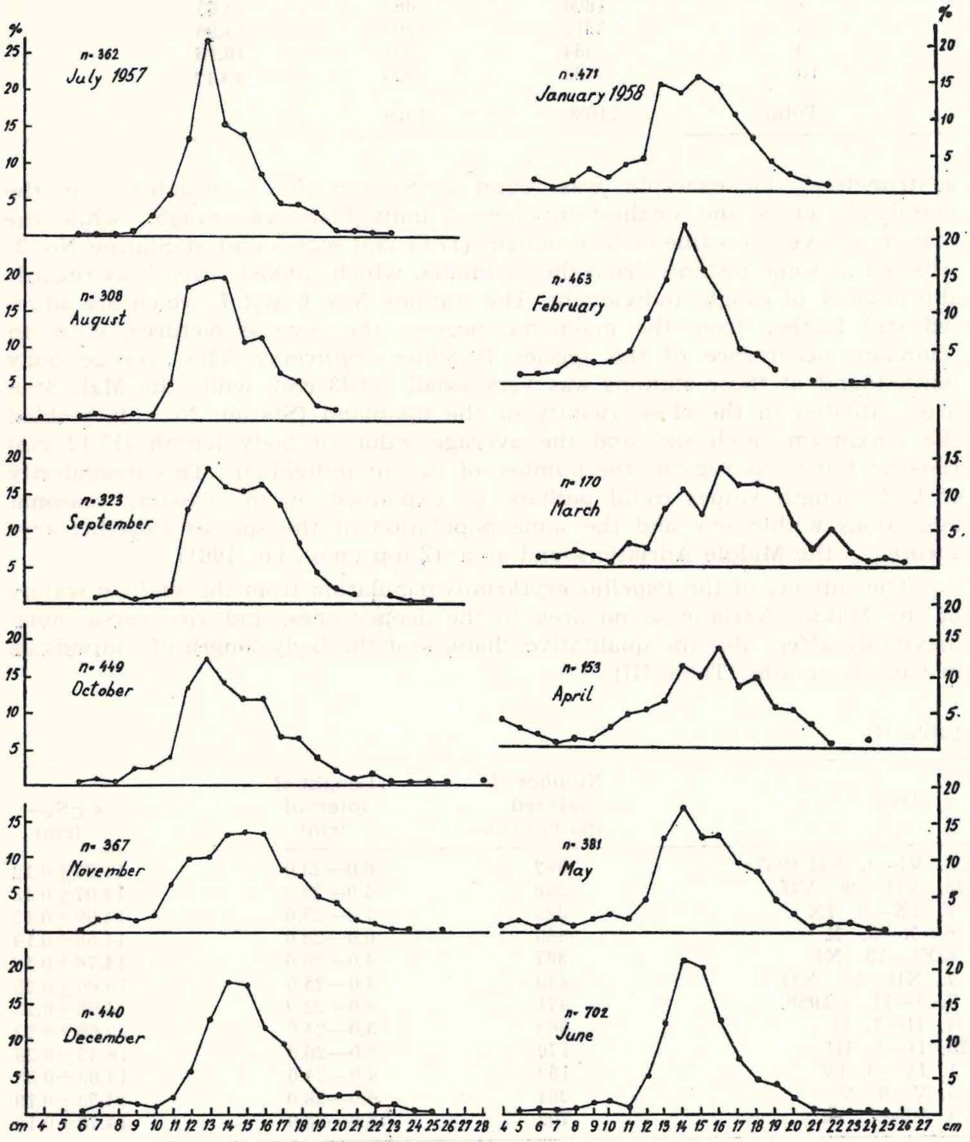

Figure 3. Length frequencies of *Pagellus erythrinus* grouped by months in 1957/1958.

2. Length and Sexual Dimorphism

By applying the statistical method of length frequencies to the both sexes, we obtain the following picture:

1. A very high ratio (almost 100 per cent) of females is found with the body length up to 130 mm.
2. The ratio of females decreases and the ratio of males increases with the body lengths between 140 and 160 mm.
3. The number of males begins to predominate with the body length of 160 mm until their ratio reaches 100 per cent with the body length of 230 mm (Table IV, Figure 4.).

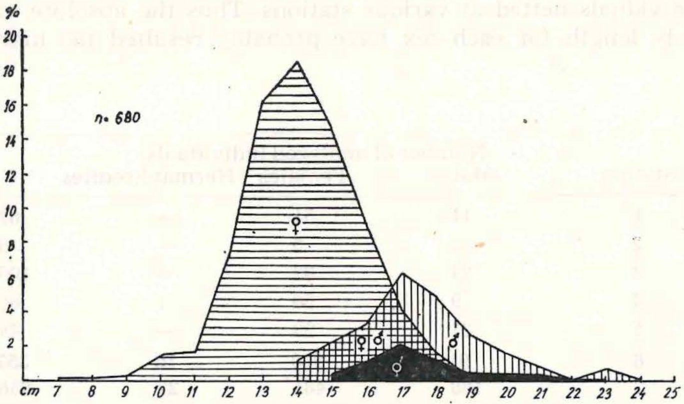

Figure 4. Length frequencies of females (horizontal line), males (vertical line), and hermaphrodites (bold line) of *Pagellus erythrinus* in the Middle Adriatic sound region in 1957/1958.

Table IV

Lenght (cm)	Number of analyzed individuals Females	Males	Hermaphrodites	Total	Relative value of quantity (%) Females	Males	Hermaprodites
7	1	—	—	1	100.00	—	—
8	1	—	—	1	100.00	—	—
9	2	—	—	2	100.00	—	—
10	10	—	—	10	100.00	—	—
11	11	—	—	11	100.00	—	—
12	49	—	—	49	100.00	—	—
13	112	—	—	112	100.00	—	—
14	127	9	—	136	93.40	6.60	—
15	99	11	4	114	86.90	9.60	3.50
16	61	18	8	87	70.10	20.70	9.20
17	25	29	14	68	36.80	42.60	20.60
18	11	21	9	41	26.80	51.20	22.00
19	2	14	5	21	9.50	66.70	23.80
20	—	8	3	11	—	72.70	27.30
21	1	3	2	6	16.70	50.00	33.30
22	1	2	1	4	25.00	50.00	25.00
23	—	3	2	5	—	60.00	40.00
24	—	—	—	—	—	—	—
25	—	—	1	1	—	—	100.00
Total	513	118	49	680			

A sex inversion takes place with this species between the third and the fourth year of life of individuals, i.e. when their body length reaches about 170 mm, and only males are found among bigger individuals (Zei and Županović, 1961).

The sex of 2,636 individuals was determined and their body length measured from June 1957 to June 1958. The sex of most of the individuals was macroscopically determined on the spot. The microscopic sex determination in the laboratory involved only 680 individuals from Table IV. The macroscopic sex determination of undersized individuals was ahmost impossible, and such individuals were not included in the analysis. This fact must inevitably affect the average body length of each sex since it has been calculated on the basis of individuals netted at various stations. Thus the absolute values of the average body length for each sex have probably resulted too high (Table V).

Table V

Station	Number of analyzed individuals			Total
	Males	Females	Hermaphrodites	
1	11	51	—	62
2	—	5	—	5
3	24	82	3	109
4	9	50	1	60
5	21	23	—	44
6	91	250	16	357
7	168	461	27	656
8	193	514	38	745
9	117	211	5	333
10	72	185	8	265
Total	706	1832	98	2636

Station	Average body lenght (cm)		
	Males	Females	Hermaphrodites
1	19.10	15.37	—
2	—	12.94	—
3	18.55	17.48	22.30
4	18.63	16.33	15.20
5	19.56	14.97	—
6	17.30	15.11	18.86
7	16.68	13.94	17.73
8	17.24	14.66	18.06
9	17.60	15.41	21.60
10	18.54	14.85	20.35
	$\overline{x}_m = 17.47$	$\overline{x}_f = 14.83$	$\overline{x}_h = 18.41$

x_m = Average lenght of males; x_f = Average lenght of females; x_h = Average lenght of hermaphrodites

The relative difference between the male body lengths, however, is rather obvious. The maximum difference between the average body length of male and female individuals was found at the Station No. 5 (4.59 centimetres), and the minimum one at the station No. 3 (1.07 centimetres). The average difference in body length between the two sexes amounts to 2.79 centimetres. All the differences are in favour of male individuals.

3. Ratio length — weight

The ratio of length to weight has become a standard method in fishery biology. It has a twofold application as it serves us, first of all, to obtain the corresponding mathematical formula enabling us to calculate the weight from the known body length of one or two individuals. And, second, any deviation from the expected, i.e. theoretical value can be helpful as an indication of the conditions of fishes, e.g. the development of gonads, etc. The ratio of weight (y) to length (x) is expressed by the formula

$$y = ax^n$$

or, transformed into the linear form:

$$\log y = \log a + n \log x$$

The constants a and n are calculated in the usual way by the linear regression method.

For the purpose of analysis, both sexes of the species *Pagellus erythrinus* were taken together owing to the inversion of sexes. The number of analyzed individuals was 192. Their exact weight (in grams) was found out, and the analyzed specimens were arranged in classes 1 cm. Average weight values were calculated for each class. The thus obtained formula for both sexes reads as follows:

$$y = 0{,}134\, x^{2{,}981}$$

The theoretical values obtained for y are shown in figure 5. The thus drawn curve of relative growth discloses two inflection points:

1. The first inflection point, between 110 and 120 mm, corresponds to the first stage of sexual maturity in females (the smallest of the female individuals with mature gonads, netted in the sounds of the Middle Adriatic, had a body length of 121 mm).
2. The second inflection point is situated between 160 and 170 mm, and is a coindicant of the sex inversion — a regular occurrence with the individuals of this species whose body length is greater then 170 mm (D'Ancona ,1949; Larrañeta, 1953, 1964; Zei and Županović, 1961; Rijavec, 1975).

C. Biology

1. Age

The method suggested by Larrañeta (1964) was employed for the purpose of age determination. Two kinds of rings are found in the scales of the species *Pagellus erythrinus:* the so-called winter rings, resulting from the

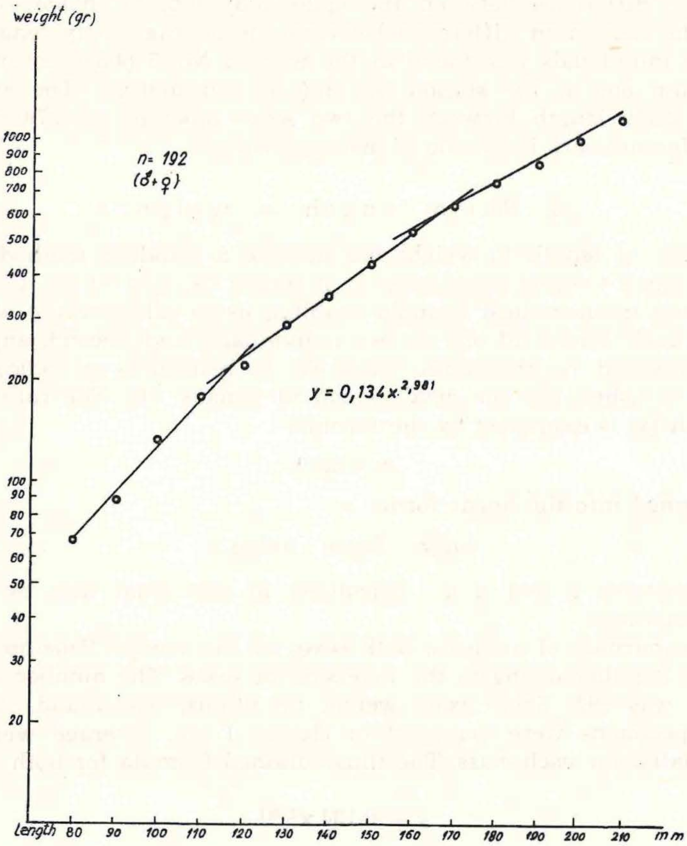

Figure 5. Average weight values of male and female individuals of *Pagellus erythrinus* in relation to length (semi-logarithmic curve).

discontinuation of growth caused by unfavourable trophical conditions in winter, and the condition rings, resulting from the discontinuation of growth of sexually mature individuals during the summer spawning. The determination of the age of individuals caught in the Mediterranean waters would be rather problematic owing to frequent mild winters in the region and to the resulting absence of winter rings, essential to the finding out of the exact age, unless the method used by Larrañeta (1963) with ctenoid scales is applied. The occurrence of inflexions of radii have been observed by this author — concave ones (considering the edge of the scale) in winter rings, and convex ones in condition rings. Thus it is possible, in case of non-occurrence of rings, to determine the age of fishes with a degree of accuracy by judging from inflexions alone.

The example of a three-year old female is shown in Figure 6 where all the five rings are noticeable. Without the application of the described method it would be very difficult, if not impossible, to determine its age.

The situation becomes worse when all the rings are not regularly formed (first a winter ring, then a condition ring, then a winter ring etc.) which precludes the possibility of estimating the age by taking into account every other ring. In such a case we are really compelled to observe the inflexions.

Four rings are noticeable in the scales of a three-year old male (3 winter rings and 1 condition ring), the third one being a condition ring, which can be judged only from the well developet inflexions of the second and third winter rings. (Figure 7.)

It frequently happens that the winter ring is not noticeable at all. In such a case, the age can be determined by inflexions alone (Figure 8).

Six age groups have been recorded in our analysis (Fig. 9).

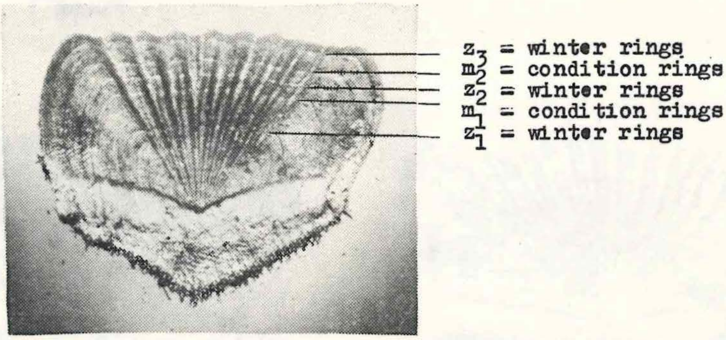

Figure 6. Scale of a three-year old female — 18,2 cm (10 times englarged).

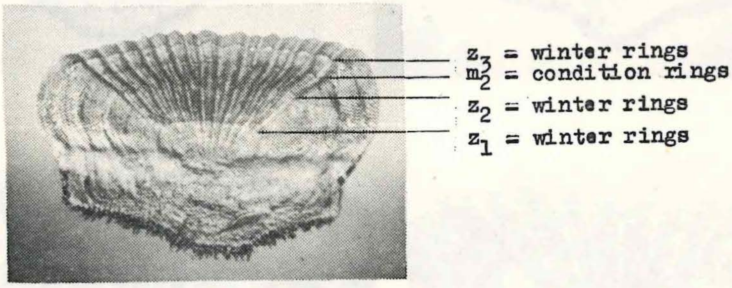

Figure 7. Scale of a three-year old male — 16,8 cm (10 times enlarged).

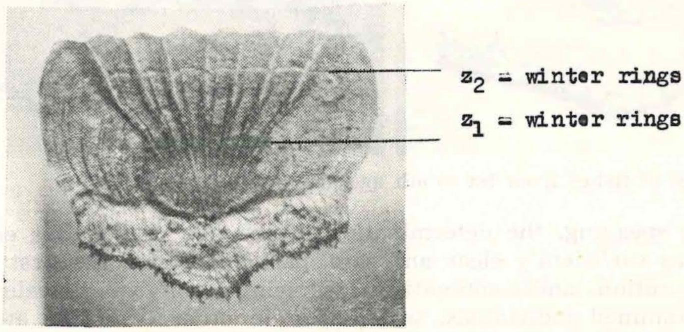

Figure 8. Scale of a two-year old male — 15,6 cm (10 times enlarged).

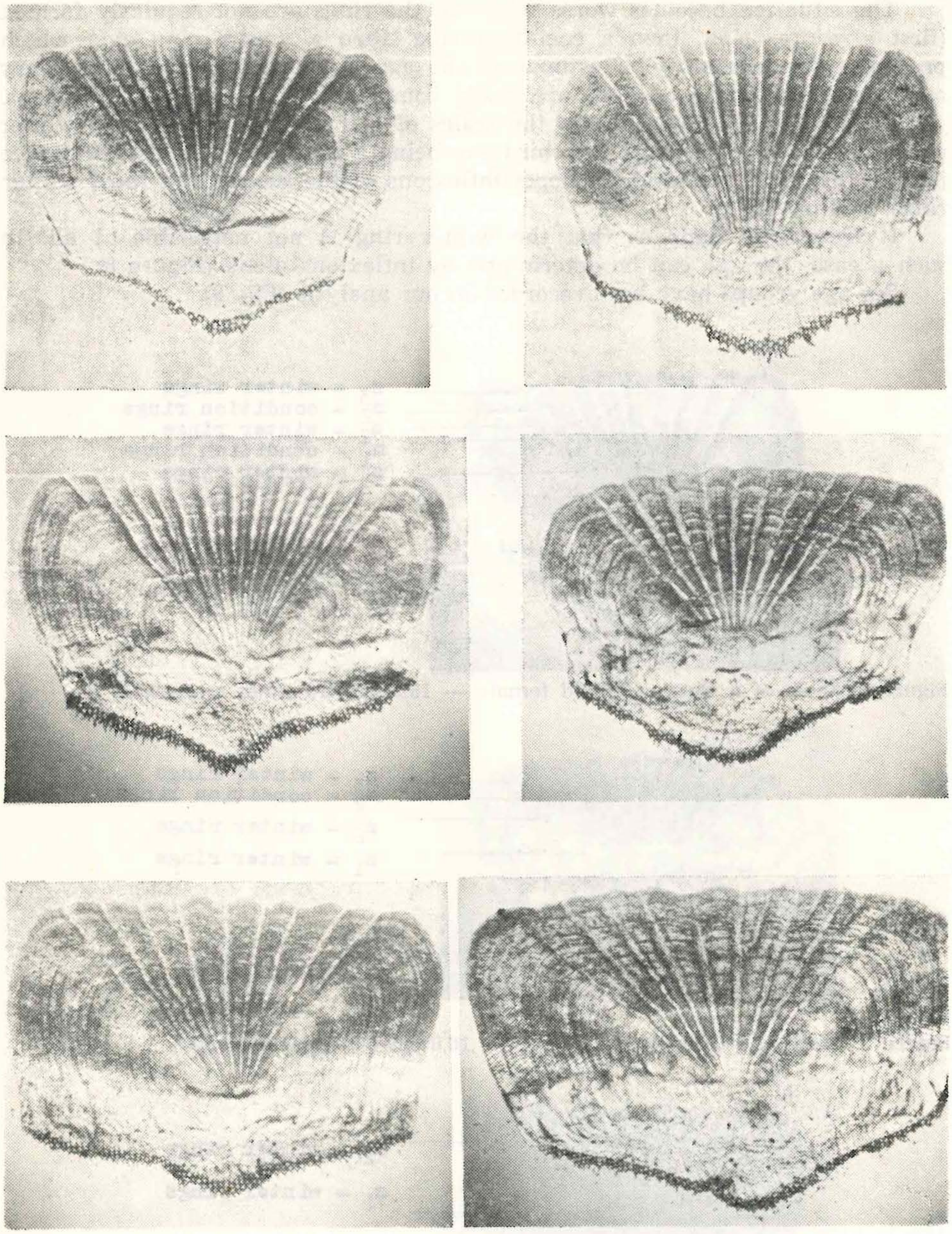

Figure 9. Scales of fishes from 1st to 6th age group (10 times enlarged).

Generally speaking, the determination of the age of *Pagellus erythrinus* individuals was sufficiently clear and safe, particularly for the first four age groups. Comparations and combinations, requiring a number of scales belonging to the examined individuals, were made in order to arrive at a result where the fifth and sixth age group were involved. To render the age determination as unbiased as possible it was performed at random, i.e. without having any previous knowledge of particulars relating to the analyzed individuals (such as length, etc.).

The total number of analyzed individuals amounted to 311; it was composed of 125 males, 179 females, and 7 hermaphrodites. Absolute and relative values of the analyzed individuals, arranged in age groups and by sexes, are given in Table VI.

Table VI

Age group	Relative Value (%) Males	Females	Hermaphrodites
I	40,00	60,00	—
II	25,00	75,00	—
III	42,98	52,89	4,13
IV	68,89	26,67	4,44
V	85,71	14,29	—
VI	100,00	—	—

Table VI

Age group	Males	Females	Hermaphrodites	Total
I	2	3	—	5
II	33	99	—	132
III	52	64	5	121
IV	31	12	2	45
V	6	1	—	7
VI	1	—	—	1
Total	125	179	7	311

The small number of individuals appearing in the first group is not the consequence of the selectivity of the net, i.e. of its ability of allowing them to pass while retaining the bigger ones (which would be a positive quality), but of the fact that individuals measuring under 13 centimetres in length (with the exception of 3 specimens) could not be analyzed since their otoliths and scales had not been collected. As will be shown in the next chapter, dealing with growth, the second age group was also unrepresentative owing to the same cause. If, bearing in mind the unreal value of the first age group. we consider the distribution of sexes within various age groups, we shall arrive at the same conclusion as in the case of distribution of sexes according to the body length of individuals (Table IV).

Females predominate in the beginning, generally up to the age of three; then both sexes become equally strong; and then the number of males starts growing until it completely outnumbers the other sexes. The inversion of sexes, occurring in the third and fourth years of age, is shown by the hermaphrodite specimens belonging to the corresponding age groups.

2. Growth

Amplitudes of body lengths within each age group, and average values of body length of all the analyzed individuals, separated by sexes, as well as the average totals irrespective of sex are given.

The first column in Table VII is digrammatically represented in Figure 10. As we can see in that picture, the analyzed individuals are rather ordinarily distributed according to their age groups. We can also find that the amplitudes of body lengths are rather large as far as some ages are concerned. This is easily explained by the fact that samples for the purpose of growth analy-

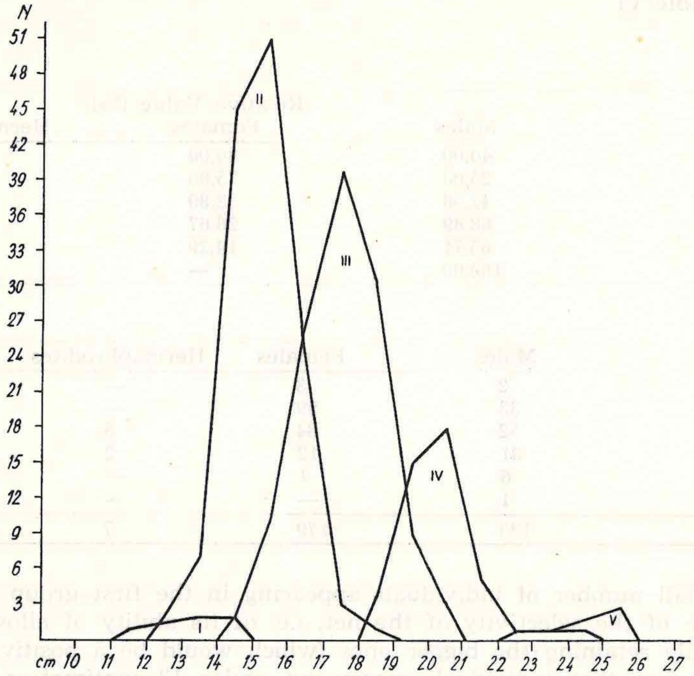

Figure 10. Frequency distribution of *Pagellus erythrinus* in the insular zone of the Middle Adriatic in 1957/1958 — according to the length and age of individuals.

ses were taken all the year round. Thus it is possible that, in an extreme case, a two-year old specimen was netted early in spring, i.e. when its growing had stopped, while another two-year old one had been netted late in autumn, i.e. before its growing stopped. It is quite understandable that their lengths can differ widely from each other. If also some common genetic and ecologic factors are considered — factors that may accelerate or retard the growth — we shall not deem it unnormal to find, for example, that the difference between the lengths of the biggest and the smallest individuals belonging to the fourth age group should amount to 5.9 centimetres.

The mode of curves of the first three age groups are too near one another. From the so obtained mode we could draw the conclusion that the average body lengths of various age groups differ but little in the beginning (the last four columns in the Table VII). This would then signify that the growth of individuals is a slow one until they reach the age of three and that their subsequent development becomes quicker, which would be quite unusual. This

Table VII

Age group	Length amplitude (cm)	Mean body lenths Males (cm)	Females (cm)	Hermaphrodites (cm)	Total
I	11,5—14,3	13,20	13,40	—	13,30
II	12,6—18,0	15,15	15,36	—	15,20
III	14,6—20,1	17,86	17,18	17,58	17,49
IV	18,3—24,2	21,02	21,15	22,95	21,20
V	22,2—25,6	24,42	24,10	—	24,21
VI		26,70*	—	—	26,70*

* Only one specimen

apparent anomaly is caused by the unrepresentativeness of the first two age groups which has already been discussed (which the exception of three specimens) were not considered which, in the opinion of the authors, added a great deal to the average body length of the two first age groups.

Von Bertalanffy's equation of growth, modified according to Beverton and Holt (1957), was used to calculate the measure of growth. In the equation, reading as follows,

$$l_t = L_\infty (1 - e^{-K(t - t_0)}) \quad (1)$$

theree constants are given:

L = limit value of body length, i.e. the theoretical maximum length attainable in the life history of an individual.

K = growth coefficient or, in mathematical language, the measure by which the shope of a curve is estimated. The greater the K the stepper the slope, i.e. the curve draws nearer the upper asymptotic value, this signifying a quicker growth of individuals.

t_0 = hypothetical value of time where the individuals, if they were always growing in the way as given by the equation (1) would have a length of 0 centimetres.

Time (t) is an indepedent value, while length at a given time (l_t) is a dependent value (i.e. it is the average body length of all the individuals within a given age group). As universally used in theoretical investigations, *e* is the base of the natural logarithm. While the l_t is measured by us, two constants remain unknown, the K and L_∞, but the are easy to calculate by entering in the equation (1) the values of average body lengths for the periods $t - 1$, t, and $t + 1$. The equations obtained in this way will read as follows:

$$K = \log_e \frac{l_t - l_{t-1}}{l_{t+1} - l_t} \quad (2)$$

$$L_\infty = l_t + \frac{(l_{t+1} - l_t)(l_t - l_{t-1})}{(l_t - l_{t-1})(l_{t-1} - l_t)} \quad (3)$$

The growth coefficient K can be calculated in this way for any period of life; the same applies to the estimate of the L_∞.

The theoretical value of the t_0 constant for all l_t sample values is calculated from the obtained K and L_∞ constants on the basis of the following equation:

$$t_0 = t + \frac{1}{K} \log_e \frac{(L_\infty - l_t)}{L_\infty}$$

The mean value ($t_0 = -0.093$) is calculated from the values obtained for t_0 and is then inserted in the equation (1). Thus we arrive at theoretical mean values of body length involving all the age groups. Values of average body lengths involving the first and second age groups (7.71 centimetres, and 13.10 centimetres) the sample values of which were unrepresentative, are then obtained by extrapolation. It is obvious that, owing to their abnormal deviations from theoretical values, the first two age groups will be left out of consideration in our further analyses of growth as if not completely represented in the catches (owing to selectivity of the like). Figure 11 contains two curves showing the growth of *Pagellus erythrinus*. The curve obtained from samples is shown by the bold line, while the dashed line represents the theoretical curve of growth obtained.

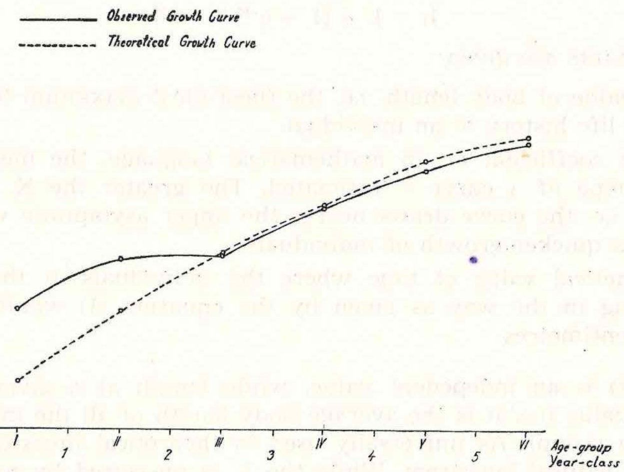

Figure 11. Growth Curve of *Pagellus erythrinus* in the insular zone of the Middle Adriatic in 1957/1958.

The exponential equation of growth $l_t = B - Ce^{-Kt}$ (B, C, and K are constants) is given for the right hand half of the curve (Figure 11), taking a slighter slope and thus being more illustrative for age groups involving older individuals (Ricker, 1958). So the lack of representativeness in the case of the first two age groups does not make our growth analysis essentially difficult.

Judging from the values resulting from our arithmetical method, i.e. $K = 0.20$, and $L_\infty = 37.88$, we can conclude that the growth of *Pagellus erythrinus* is relatively a slow one in the sounds of the Middle Adriatic, and that the species, therefore, reaches a considerable size. Growth parameters of

Pagellus erythrinus in the Boka Kotorska Bay obtained by arithemetical method were: K = 0,239; L'_{∞} = 30,92 cm (Rijavec, 1975).

In a much simpler and quicker way, but with a lesser degree of accuracy, the value of the equation (1) constants can be obtained graphically by employing the well-known method suggested by Walford (1946) or the one suggested by Gulland and Holt (1959); the differences between the body lengths of two adjoining age groups ($L_{t+1} - l_t$) are entered in the ordinate, and the mean body length of those two age groups are entered in the abscissa (Figure 12). The resulting points are connected (the first and the second age groups are again omitted), and the slope coefficient of the so obtained straight line is K = 0,201 while the point of intersection of that line with the abscissa is L'_{∞} = 37,7 cm. Growth parameters of *Pagellus erythrinus* in the Boka Kotorska Bay obtained by graphic method were: K = 0,245; L_{∞} = 30 cm (Rijavec, 1975).

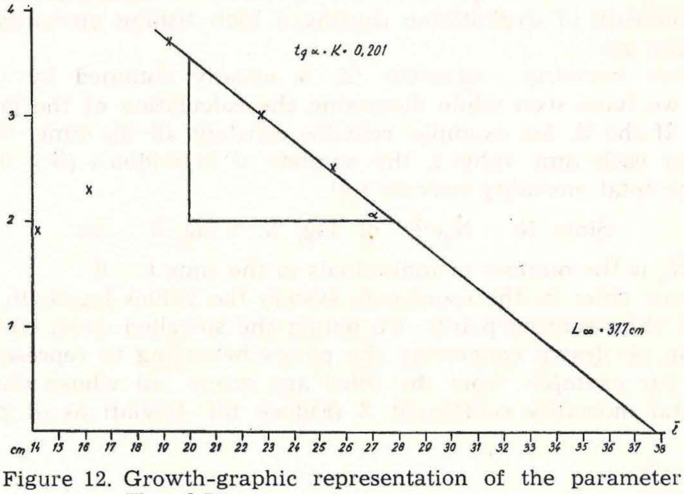

Figure 12. Growth-graphic representation of the parameter K and L∞

3. Analysis of Growth by Sexes

The rate of growth of marine animals is usually higher in females than in males. Being interested to learn whether this applies to the species *Pagellus erythrinus* too, we have calculated, availing ourselves of the methods mentioned in the foregoing pages, the growth coefficients for both sexes. The resulting coefficients, K = 0.165 for males, and K = 0.30 for females, confirm our surmise as to the different rates of growth with regard to sexes.

4. Mortality

The mortality of a sea fish species represents the most interesting factor in fishery biology the estimation of which is highly problematical. When the mortality is calculated, it is supposed that the population is equally distributed over an area, that it is equally exploited, and that it is not subject to migrations. This, however, rarely happens under natural conditions.

Let us suppose that all the above conditions have generally been fulfilled. If we now have a definive numerical value of individuals N_1 in the age group a, the numerical value N_2 in the next age group a + 1 will then be expressed by the following equation:

$$N_2 = N_1 e^{-Z} \quad \text{or} \quad Z = \log_e \frac{N_1}{N_2}$$

where e stands for the base of the natural logarithm, while Z represents the total mortality coefficient. Z is, consequently the natural logarithm of the quotient of N_1 and N_2 values.

In our example, where the Z has the value of 1.50, the annual proportion of the surviving population is only 21 per cent. Such a high value of the total mortality coefficient (provided the estimate is accurate), mainly results from the intensity of exploitation causing a high fishing mortality preceding our investigations.

The total mortality coefficient (Z) is usually obtained by the graphic method as we have seen while discussing the calculation of the growth coefficient (K). If the Z, for example, remains constant all the time, we can then calculate, for each time value t, the number of individuals (N_t) of a definite age after the total mortality took its toll.

$$\text{Since } N_t = N_0 e^{-Zt}, \text{ or } \log_e N_t = \log_e N_0 - Zt$$

where the N_0 is the number of individuals in the time $t = 0$.

If we now enter in the coordinate system the values $\log_e N_t$ in the time t and connect the resulting points, we obtain the so-called catch curve. A straight line can be drawn connecting the points belonging to representative age groups (in our example, from the third age group on) whose slope (tg α) is just our total mortality coefficient Z (Figure 13). Deviations of points from

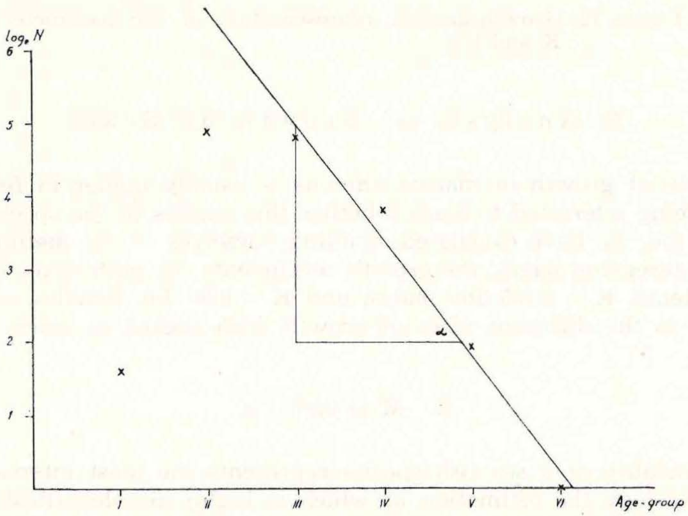

Figure 13. Mortality-graphic calculation of the coefficient Z.

that line are the consequence of non-fulfilment of the condition mentioned in the beginning of this paper. The advantage of this graphic method lies in the fact that te possible variations in the availability of a fish population can only alter the position of the curve, without affecting its shape or slope as it happens when the numerical values of an age group at different periods are entered.

As evident from Figure 13, the obtained estimate of the total mortality coefficient Z (1,57) is almost completely identical with the estimate obtained in the arithmetical way which indicates that the Z (1,50) was rather constant.

DISCUSSION

By surveying our data shown in Figure 2 we can see that the edaphic factor, most probably, does not play an important part in the distribution of *Pagellus erythinus* (L.) in the insular zone of the Middle Adriatic. Rijavec (1975) has also found that the textural caracteristics of the bottom did not effect the distribution of this species in the Bokakotorska Bay. According to the same author the most important factor which seemed to affect the distribution of *Pagellus erythrinus* was the quantity of the available food. Županović (1961) has supposed that the effect of hydrographic factors (temperature and salinity) on the size of catches of *Pagellus erythrinus* is much more evident.

Seasonal emigration and immigrations of *Pagellus erythrinus* from the shallow waters to the deeper, ones, and vice versa, was observed in the insular zone of the Middle Adriatic. Rijavec (1975) has also registered the same phenomenon in the Bokokotorska Bay.

The theoretical curves of weight in relation to length show two inflexion points which correspond to the first maturity of females (110—120 mm) and to the process of sex inversion (160—170 mm). The inversion of sexes occured in the third and fourth year of age as shown by the hermaphrodite specimens belonging to the corresponding age groups.

The theoretical curve of relative growth of the species *Pagellus erythrinus* in the waters of the Tuscan archipelago shows-according to Matta (1959) — only one inflexion point (between 120 and 130 centimetres). The resulting difference, in our opinion, could be explained by the insufficient number of analyzed individuals (49) netted in the waters of the Tuscan archipelago.

Rijavec (1975) has found two points of inflexion (125—135 mm and 185—195 mm) in the Bokakotorska Bay.

Giving a description of his own method of age determination from ctenoid scales, Larrañeta (1964) illustrated a number of pictures of the *Pagellus erythrinus* scales. Specimens as big as 170 and 196 mm, belonging to the first and second age groups respectively, etc., are indicating a possibility of quicker growth of *Pagellus erythrinus* at Castellone than in the Adriatic. A higher average temperature of sea water both in summer and in winter, and a larger plancton biomass (according to the estimate of the FAO 56/8/6299), in that area twice as large as the Adriatic, and probably also a larger amount of zoomass in general, may substantiate the above hypothesis.

It has been found by D'Ancona (1949) that *Pagellus erythrinus* individuals of the Adriatic area reach a length from 170 to 175 mm in their third year of life which is in agreement with the results obtained by us.

The growth parameters of *Pagellus erythrinus* in the insular zone of the Middle Adriatic were: K = 0,201 and L_∞ = 37,7 cm. Judging from the values resulting from our graphic method we can conclude that the growth of *Pagellus erythrinus* is relativevy a slow one and that the species, therefore, reaches a considerable length.

Growth parameters of *Pagellus erythrinus* in the Bokakotorska Bay were: K = 0,245 and L_∞ = 30 cm (Rijavec, 1975). The obtained values show an inverse relation.

The total mortality coefficient (Z) in the insular zone od the Middle Adriatic was relatively very high (Z = 1,57). Such a high value of the mortality coefficient (provided the estimate is accurate) was obtained as result of an exploitation causing a high fishing mortality preceding our investigations.

As the trawling in the Bokakotorska Bay has been forbidden for many years the total mortality coefficient is relatively low (Z = 0.63) so that more than half of the population remains in life each year (in the insular zone of the Middle Adriatic the annual surviving population is only 21 per cent).

Unfortunately enough, the concerning data includes a period of only one year and, consequently, the age-group frequencies are comparable only within that one-year space of time. The error of our estimate may be partially avoided only if a large number of age groups is available, so that the estimated total mortality coefficient represents the mean value of all the calculated coefficients for various age groups.

CONCLUSIONS

The following conclusions can be drawn on the basis of the obtained results:

1. The distribution of the species *Pagellus erythrinus* in the insular zone of the Middle Adriatic is strictly limited by the 100 metres isobath.

2. The body length of 4,589 specimens, out of 11,686 netted ones, was measured. The mean body length of the whole population amounts to 14.76 ± 1.26 centimetres.

3. Frequent migrations occur within the *Pagellus erythrinus* population in the insular zone of the Middle Adriatic. Migrations of the species from shallow waters towards deeper ones were observed in the period between October and April, and in the opposite direction between May and October. These seasonal migrations are reflected both in the variations of population abundance at various stations and in various months, as well as in the variations of body length and dominant mode in the area in various months.

4. Females predominate in the population up to the body length of 130 mm; the number of females starts dropping and that of males growing with body lengths between 140 and 160 mm; the number of males starts predominating until its reaches its highest value (100 per cent) with the body length of 230 mm.

5. The value of the equilibrium constant (n) in the ratio length to weight is equal to 2.981. The theoretical curve shows two points of inflection: between 110 and 120 mm, corresponding to the occurrence of the early sexual maturity, and between 160 and 170 mm, coinciding with the normal sex inversion occurring with this species.

6. The sexes were distributed in six age groups. Females predominated until the third year of age, and then the males took over. The appearance of hermaphrodites in the third and fourth age groups indicates the occurrence of sex inversion.

7. The calculated theoretical growth curve is in good agreement with the empiric curve, except in connexion with the first two age groups which appear to be unrepresentative owing to the fact that their scales were not collected for the purpose of age determination (with the exception of 3 specimens).

8. Growth parameters of *Pagellus erythrinus* in the insular zone of the Middle Adriatic were: $K = 0.201$; $L_\infty = 37{,}7$ cm. The conclusion can be drawn that the rate of growth of *Pagellus erythrinus* in the insular zone of the Middle Adriatic is relatively low and that the individuals, consequently, reach a considerable length.

9. The growth analysis performed for each sex separately has shown that the females of the species *Pagellus erythrinus* grow faster than the males, which is a frequent phenomenon with sea fishes.

10. The estimate of the total mortality coefficient Z obtained in the graphical way ($Z = 1.57$) is almost completely identical with the arithmetically obtained estimate which indicates that the Z was rather constant. The high value of thus calculated Z can generally be attributed to the high degree of exploitation of the area preceding our investigations.

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BIOLOGIJA I DINAMIKA POPULACIJE *PAGELLUS ERYTHRINUS* (L.) U OBALNOM PODRUČJU SREDNJEG JADRANA

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KRATKI SADRŽAJ

U ovom su radu autori iznijeli rezultate istraživanja biologije i dinamike populacije arbuna (*Pagellus erythrinus* L.) u obalnom području srednjeg Jadrana.

Izučavanja su obuhvatila slijedeću problematiku: zoo-geografsku distribuciju, sezonske varijacije, odnos dužine i spolnog dimorfizma, odnos dužine—težine, starost, rastenje i mortalitet.

Na osnovu dobivenih rezultata izvedeni su slijedeći zaključci:

1. Zoo-geografska distribucija arbuna (*Pagellus erythrinus,* L.) u području srednjeg Jadrana ne prelazi izobatu od 100 metara dubine (Slika 2).

2. Srednja duljina *Pagellus erythrinus* u istom području, izmjerena na osnovu 4589 primjeraka, iznosila je 14,76 $\pm$ 1,26 cm.

3. Uočene su izvjesne migracije *Pagellus erythrinus-a* u obalnom području srednjeg Jadrana. Lokalno pomicanje iz plićih u dublje vode konstatirane su između listopada i travnja mjeseca i vice versa od svibnja do listopada. Te sezonske varijacije *Pagellus erythrinus-a* odražavaju se ne samo na varijacije gustoće populacije na raznim postajama, već i na varijacije duljina i dominantnog modusa u vremenu i prostoru.

4. Ženke su dominantnije u populaciji do tjelesne duljine od 130 cm; između 140—160 cm broj ženka opada, a mužjaka raste. Nakon toga broj mužjaka raste i postaje (100%) sa tjelesnom duljinom od 230 mm.

5. Odnos između duljine i težine *Pagellus erythrinus* u obalnom području srednjeg Jadrana bio je: n = 2,981. Teoretska krivulja pokazuje dvostruku tačku infleksije: između 110—120 i drugu između 160—170 cm, što koincidira sa normalnom inverzijom spola kod ove vrste.

6. Spolovi su bili raspoređeni u šest starosnih grupa. Ženke su dominirale do treće starosne grupe, a nakon toga mužjaci. Pojava hermafrodita u trećoj i četvrtoj starosnoj grupi, ukazuje na pojavu inverzije spola kod *Pagellus erythrinus.*

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* Od 1969. godine suautor se ovog rada nalazi u službi organizacije za ishranu i poljoprivredu Ujedinjenih naroda (FAO) kao ribarstveni stručnjak.

7. Izračunata teoretska krivulja rasta dobro se poklapa sa empirijskom, osim kod prve dvije starostne grupe, koje se pokazuju reprezentativne zbog malenog broja primjeraka.

8. Parametri rastenja *Pagellus erythrinus* u obalnom području srednjeg Jadrana bili su ovi: K = 0,201; L_∞ = 37,7 cm. Na osnovu dobivenih vrijednosti izveden je zaključak da je rastenje *Pagellus erythrinus* u obalnom području srednjeg Jadrana relativno sporo i da zbog toga postizava znatnu dužinu.

9. Analiza rastenja, podijeljena po spolovima, ukazuje da ženke *Pagellus erythrinus* rastu brže od mužjaka, što je česti fenomen kod riba.

10. Procjena totalnog mortaliteta (Z), dobivena grafičkom metodom, bila je: Z = 1,57. Tako visoka vrijednost Z ukazuje na znatan stepen eksploatacije dotičnog područja prije samog istraživanja.