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THE FECUNDITY OF HAKE (*MERLUCCIUS MERLUCCIUS* L.) AND RED PANDORA (*PAGELLUS ERYTHRINUS* L.) IN GREEK SEAS

FEKUNDITET OSLIĆA (*MERLUCCIUS MERLUCCIUS* L.) I ARBUNA (*PAGELLUS ERYTHRINUS* L.) IZ GRČKIH VODA

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The fecundity of hake, *Merluccius merluccius*, and red pandora, *Pagellus erythrinus*, was investigated from 55 and 27 specimens respectively. There were no significant correlations between the size of the eggs and the size of the fish. Diameters of mature oocytes ranged from 0.45 to 0.80 and 0.35 to 0.60 mm for hake and red pandora respectively. Fecundity ranged from 24,000 to 296,300 and 22,000 to 362,000 mature ova for hake and red pandora. Fecundity increased exponentially with fish length, weight and age in both species. The correlation between fecundity and length and between fecundity and weight being slightly better than that between fecundity and age.

INTRODUCTION

Knowledge of fish fecundity is useful in determining radial and environmental differences, in investigating population dynamics of a fish species and for fish culture purposes. The relationship between a species length and its fecundity has been used principally as a rapid means of predicting the fecundity of fish stocks when their lengths are known. Typically, fecundity increases as length increases until a state of senility sets in.

Although hake (*Merluccius merluccius*) and red pandora (*Pagellus erythrinus*) are among the most valuable commercial fish in the Mediterranean Sea, almost nothing has been published concerning the fecundity of these species, with the exception of a preliminary study on hake (Tsimenidis and Papaconstantinou, 1985).

As a contribution to the knowledge of the biology of hake and red pandora in the Greek Seas, this study presents information on the fecundity of the species in relation to some parameters such as lenght and age.

MATERIALS AND METHODS

The present study is based on samples of hake and red pandora taken in the Saronikos Gulf and Patraikos Gulf respectively.

Subsample of mature females, 55 hake and 27 red pandora, were collected for fecundity studies. All specimens were preserved in 8% formalin upon capture. Total length (TL) for hake and fork length (FL) for red pandora in mm were recorded. The body weight was measured to the nearest 0.1 g.

A gonad maturity stage was assigned to each specimen using the sexual development classification and criteria proposed by Nikolsky (1976). The ovaries from each fish were carefully removed, weighed to the nearest 0.01 g, and placed in a bottle containing modified Gilson's fluid (Simpson, 1951). This solution not only preserves the eggs, but also breaks down the intraovarian connective tissues after several weeks without damage to the ova. Eggs left in Gilson's fluid for more than 2 or 3 months were found to be in poor condition and had to be discarded.

After two month preservation, the ovaries were washed thoroughly in cold water over a series of stainless steel screens with opening of 0.5, 0.25, and 0.125 mm in order to separate the eggs into the size ranges >0.5, 0.25—0.5 and 0.125—0.25 mm. After cleaning, the ova were stored in a solution of 2-ethoxyethanol for several days. This solution allows the ova to harden and prevents clumping by breaking down any excessive greasy or fatty material. Finally, the cleaned eggs were stored in 5% formaldehyde solution until counting. Oocyte diameters were measured using a binocular microscope fitted with an eypiece micrometer.

Fecundity was determined for both maturing gonads by relating the number of eggs in a subsample to the whole gonad. Volumetric determinations were made by dropping ovaries and samples therefrom into circumferentially-lined Klet test tubes, then withdrawing the water displaced with finely-calibrated serological pipettes. Gravimetric determinations were made by weighing the same ovaries and their sample sections to the nearest milligram on a Mettler balance. Essentially, both methods involved taking the weight or volume of a known number of mature ova and proportionally computing the total number of eggs in both ovaries was calculated by using the following formula:

$$\text{fecundity} = \frac{Wt}{Ws} \times N$$

where N = number of eggs in the sample, Wt = weight or volume of the ovary and Ws weight or volume of the sample.

Since the analysis of variance tests showed insignificant difference in the weight or number of counted ova from the left and right ovaries we used either ovary for measurements and counts (Table 1).

Table 1. Analysis of variance (F' test) of the weight and number of counted ova of the left and right ovaries

Species	Weigth of ova			Number of ova		
	F	df	P	F	df	P
Hake	2.76	43	P > 0.05	3.53	47	P > 0.05
Red pandora	2.09	26	P > 0.05	3.71	26	P > 0.05

Analysis of covariance was used to test the between year differences of fecundity vs: length and weight. No significant differences were indicated; therefore regression equations were used for pooled data (Table 2).

Table 2. Analysis of covariance of fecundity v.s. length and weight, in two consecutive years

Species	Relation between fecundity and length			Relation between fecundity and weight		
	F	$df^1/_2$	P	F	df	P
Hake	6.62	1/26	P > 0.05	5.79	1/26	P > 0.05
Red pandora	4.73	1/18	P > 0.05	5.88	1/18	P > 0.05

Scales and otoliths were removed from red pandora and hake respectively, while they were in fresh condition. Scale samples for aging were taken from the left side of the body, along the middline and below the origin of the dorsal fin. Scales were read with microprojector and the annuli were easily recognized. Otoliths were placed in a black bakelite dish containing some millimetres of glycerin and studied under a stereoscopic binocular microscope using reflecting light.

RESULTS

Hake

Egg size

Hake mature at 30.0—33.0 cm TL as they approach age 3+. Gonad development was obvious at 28.0—31.0 cm, as most specimens entered the early development stage. The ripe ovaries occupy the greatest part of the body cavity and have a brown-dirty white colour. The two ovaries are almost equal in lenght and size, but, on spawning time, they present some slight differences. The dorsal margin of each ovary is folded, while the ventral side is devoid of folds. Although hake spawns over a broad time period in Greek seas (Tsimenidis *et al.*, 1977), spawning primarily occurs during two discrete periods; a March spawn and a summer spawn with the gonads at maturation stages from late June through August.

Data were obtained from 55 female hake sampled immediately before spawning. The length of the females ranged from 29.8—63.2 cm, (average

43.2 cm) and their ages from 3+ to 9+ (Fig. 1). Total number of egg size-class larger than 0.25 mm per female ranged from 80,000—1,800,000, (average 310,000) and the mean mature oocyte diameter ranged from 0.43 to 0.69 mm. All oocytes smaller than 0.25 mm in diameter were classified as immature on the basis of preliminary comparisons of oocyte size frequencies for juvenile and adult specimens.

There was no positive correlation between mean diameter of mature oocytes and length or age of the fish. There was no significant difference between the diameters of oocyte size-classes greater than 0.5 mm, sampled during the spring of the two sampling years (one-way analysis of variance,

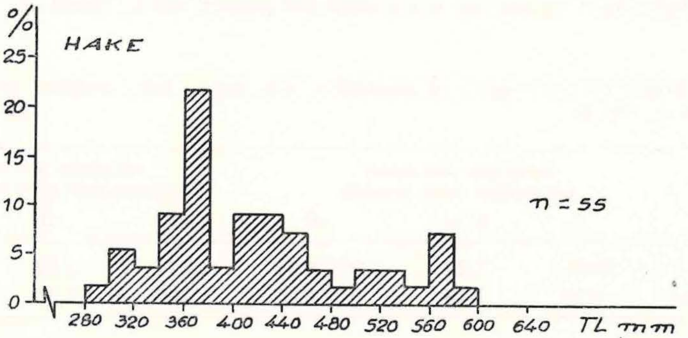

Fig. 1. Length-frequency distribution of hake caught in the Greek Seas in June 1983 — June 1984 for fecundity studies

$F = 0.95 > 0.05$). Two-way analysis of variance of diameter of the largest oocyte size-class from 12 ovaries for spring and summer samples showed significant differences not only between ovaries from both seasons ($F = 43.05$; $P < 0.001$), but also within the same season.

The interaction term was also significant ($F = 03.43$; $P < 0.001$), indicating that the rate of oocyte development varied significantly among the fish of the same sample. No relation was observed between the egg-size and the length of hake. Frequency distribution of 1.25 million ova diameter measurements larger than 0.20 mm taken from five mature fish, ranging from 30.5 to 57.0 cm and collected between summer and winter showed two maturing modes (Fig. 2); one most highly developed ova mode between 0.60—0.76 mm and a second mode between 0.32—0.44 mm. Clark (1934) and Rpabhu (1956) interpreted the presence of various egg sizes in the ovary as an indication of multiple spawning. The presence of two size groups of maturing ova and the occurrence of juvenile (young of the year) from September to March in the Greek Seas suggested multiple spawning of the species or the presence of different populations.

Fecundity is here defined as the total number of ova, with diameter larger than 0.5 mm, that mature in both ovaries in one season. The estimates ranged from 10,100 eggs for a 41.0 cm fish to 535,000 eggs for a 63.2 cm

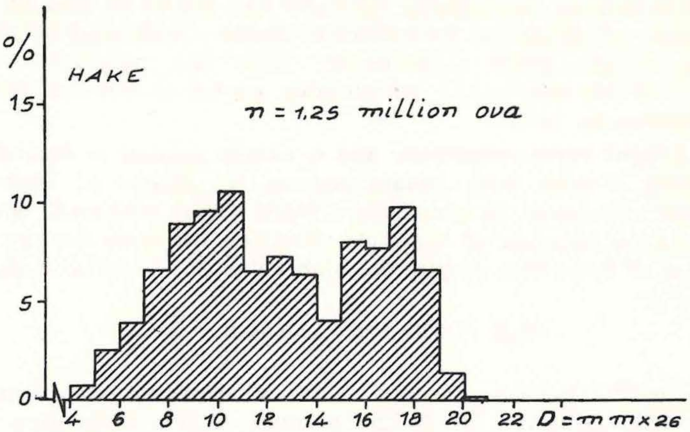

Fig. 2. Frequency of oocyte diameters for hake in the Greek Seas

specimen; most of the fish were in the range 36.0—48.0 cm and fecundity estimates generally ranged between 30,000 and 150,000 ova.

There was considerable variation in fecundity of individuals. The range in age, weight and length of individuals in the sample suggested that it would be desirable to examine in detail these variables and their relationship to fecundity. Various equations were examined in order to choose the one best fitting the data: length, weight or age- fecunddity. For this choice, we used the criterion of the smaller mean square error MSE (SSR) between observed and calculated fecundity, combined with the possibility of interpreting the equation biologically. Two of these are polynomials (first and second degree) and the third is a power function. The power function was finally chosen, despite not having the lowest MSE, because the fecundity estimated for the younger hake using linear regression led to negative fecundity, having no biological meaning and the loss in terms of MSE was not regarded as significant.

From the scatter diagram of fecundity against body length it is apparent that fecundity increases at a rate greater than the length of the fish. Regression analysis indicated that the total length, weight or age could be used to predict fecundity of hake, but age proved to be best related to fecundity ($r = 0.735$) an had the lowest error mean square. Combinations of three independent variables, weight, length and age improved predictability only slightly, therefore, separate equations were derived by using weight, length and age on fecundity.

Regression analysis showed that fecundity estimation (F = 000's ova) increased with length and age, according to the equations:

$$\log F = 3.33 \log TL - 3.52 \qquad r = 0.72 \quad n = 55$$
$$\log F = 2.06 \log A + 0.4 \qquad r = 0.735 \quad n = 55$$

where TL is the total length in cm, A the age in years and r the correlation coefficient.

The equations for the females (29.8 and 63.2 cm or III and IX years old) give minimum and maximum fecundities of 24,000—24,250 and 231,900—296,300 respectively, which differ substantially from the measured number of eggs. This is rather due to the considerable scatter of the individuals points about the regression line.

Gonad weight varies sesasonaly and is closely related to fecundity; therefore, removing it from body weight reduces the degree of autocorrelation. Even without the gonad weight, body weight varies seasonally and to some extent daily as a function of the diet; therefore the body weight is not the best predictor of fecundity, despite the high value of $r = 0.710$ in the equation.

$$\log F = 0.99 \log W - 0.94 \quad n = 55$$

The fecundity to ovary weight (OW) relationship was expressed by: $F = 19.23 + 7.16$ (OW) $n = 55$. It had a much higher correlation coefficient (0.952) than the length, age or body weight regressions. To minimize the influence of the monthly variation, Morse (1980) suggests that prediction of fecundity should be derived from ovary weight only at the peak spawning month.

Red pandora

Egg size

Mature red pandora of Greek seas generally spawn during May and June, but a few may spawn in middle April and also in late September. The variation in spawning time are largely related to hydrographic condition throughout the area during the preceding months. The ripe ovaries occupy the greatest part of the body cavity and have an orange to yellow colour. The two ovaries are almost equal in length and size, but, on spawning time, they present some slight difference. Red pandora mature at 15.0—16.0 cm FL as they approach age III and spawn.

Both protandrous and protogynous hermaphroditism are relatively common among the sparids (D'Ancona, 1949; 1956). Red pandora collected from the Patraikos Gulf appear to display protogynous hermaphroditism. At first, the fish functioned as females, after which the ovaries began tranforming into testes. The predominance of females at the smaller length size of 10 cm FL is found to be around 90% in this study and the presence of individuals with both ovarian and testicular tissue supports the theory of protagyny. Although hermaphroditic red pandora were found by macroscopic examination, only 24 specimens of the 1092 examined (2.2%) contained both male, and female gonadal tissues. Hermaphroditic red pandora ranged in size from 12.8 to 20.3 cm FL (II to V age class); possibly the length range during which sexual transition takes place.

From the 27 females of the samples taken between April and June, immediatelly before spawning, data were obtained on egg number and egg diameter. The length of the females ranged from 15.5 to 28.4 cm (average 20.8 cm) and their ages fom 3+ to 9+ (Fig. 3). The total number of eggs per female ranged from 32,300 to 857,000 (average 247,000) and the mean oocyte diameter ranged from 0.16 to 0.51 mm. No positive correlation between mean diameter of mature oocytes and length or weight of the red pandora was found.

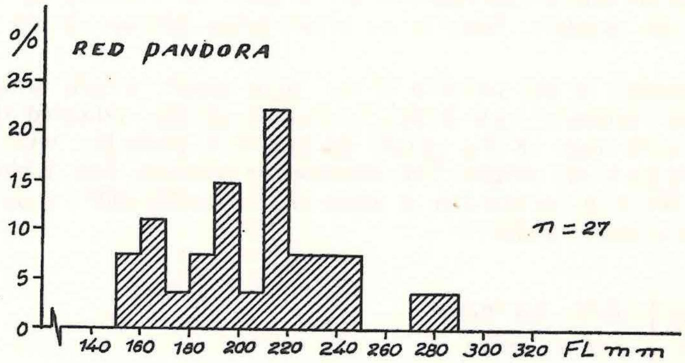

Fig. 3. Length-frequency distribution of red pandora in the Patraikos Gulf in June 1983 — June 1984 for fecundity studies

All oocytes smaller than 0.25 mm in diameter were classified as immature. Analysis of variance of diameters of oocyte size-class larger than 0.25 mm from 11 ovaries from spring, summer and early autumn samples, showed significant difference not only between ovaries from the different seasons but also between ovaries from the same season ($F_{spring} = 12.4$; $F_{summer} = 72.9$; $F_{autumn} = 72.9$; $P < 0.001$). The large value of Fsummer is rather due to the activity of the gonads, which presents a peak during summer.

Two findings indicated, that in the Patraikos Gulf population the female red pandora were fractional spawners. Firstly, the spawning season was prolonged, some famales still spawn in September, four or five months after the first spent females were captured. Secondly, the size-frequencies of the eggs from the gonads of ripe females showed that, in addition to large ripe eggs and small oocytes, there was a group of intermediate-sized oocytes. In fact, the frequency distributions of oocyte diameter from 11 fish, ranging from 17.7 to 28.4 cm and collected between 17 April and 15 June, show one seasonally progressing mode of developing ova (Fig. 4). The position of the mode varied according to the development stage of the individual ovary. A sample from 17 April had a mode between 0.15 and 0.27 mm and was skewed toward a prominent peak at 0.21 mm. It the 15 June sample, a second mode appeared around 0.52 mm. Maximum ova diameter observed was 0.65 mm from a sample on 17 April and 15 June. That ovum was filled with fluid between the yolk and chorion, indicative of an ova immediately prior to release (B a g e n a l, 1978).

Fecundity

On the basis of the ova diameter measurements in mature and spent fish, ova 0.25 mm and larger were classified as mature. The estimates of fecundity ranged from 22,200 mature eggs for a 16.5 cm fish to 362,200 eggs for a 28.4 cm specimen, averaging 91,500 eggs. It is believed (Nikolsky, 1969) that absolute fecundity and egg size are related. As revealed by correlation analysis in red pandora, there is no relationship between these two parameters.

The fecundity of red pandora of the same length, weight or age fluctuated between relatively wide limits. Regression models indicated that length and weight were more or less equally predictive of fecundity, with a slightly higher dependence on weight. The relationship between fork length (FL) in cm, weight (W) in g., or age (A) in years and fecundity (000's ova) were best described by a power curve:

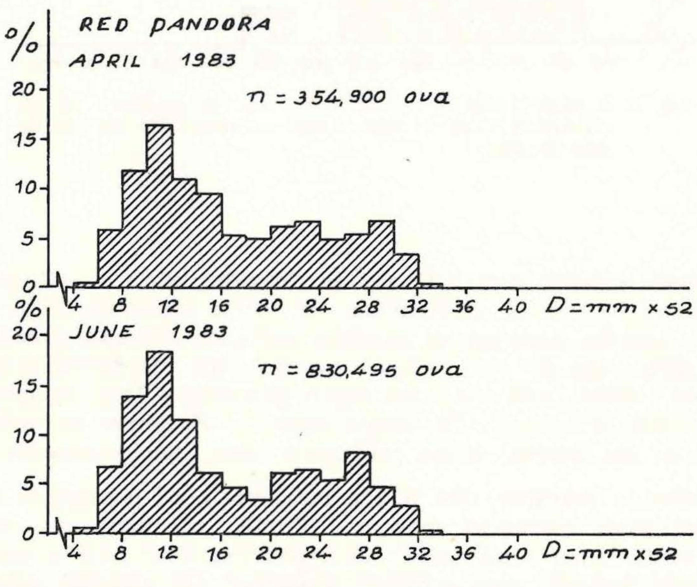

Fig. 4. Frequency of oocyte diameters for red pandora in the Patraikos Gulf for April, June 1983

$$\log F = 3.74 \log FL + \log 0.001 \qquad r = 0.838$$
$$\log F = 1.25 \log W + \log 0.121 \qquad r = 0.883$$
$$\log A = 1.71 \log A + \log 4.4 \qquad r = 0.798$$

The above relations for the smallest and largest females (15.5 and 28.4 cm) gave minimum and maximum fecundities of 26,400—28,700 and 186,900—271,500 respectivelly. These values differ from the measured ones, particularly for the large females.

For the same reasons as discussed for hake, the relationship between fecundity to ovary weight (OW), expressed by:

$$F = 1.62 + 10.15\,(OW) \qquad r = 0.945 \qquad n = 27.$$

seems to be the best relationship, but is a direct predictor of fecundity.

DISCUSSION

The accurate determination of the fecundity of a fish is time consuming and, in hake or red pandora, which produce great numbers of very small eggs in the various stages of development, the problem is especially complicated by the necessity to classify eggs on the basis of their maturity. The best approach is to decide which ova are to be considered mature and determine only their numbers through gravimetric-volumetric estimates or actual counts. If estimates are to be made, checks on their accuracy through actual counts of selected specimens should be conducted.

The range of fecundity of hake with average diameter larger than 0.5 mm of 10,000 to 535,000 eggs observed in this study, compares favorably with reported fecundity in previous studies (Tsimenidis and Papaconstantinou, 1985). However, the many variables that influence fecundity make comparisons difficult. As regards the fecundity of red pandora no previous reference was found.

The absolute fecundity of the female hake of equal body size increases with age and the Student's criterion was used to test the significance of the difference between mean absolute fecundity of equal age females. The samples of red pandora indicate that a relationship similar to that for hake also exists, but the small number of individuals did not allow the accurate use of Student's criterion. Raih (1933) reported for North Sea haddock that fecundity, in fish of the same size, was greater for older fish. The present fecundity observations on hake and red pandora from Greek Seas appear to corroborate this wiew, although Simpson (1951) found for North Sea plaice that the older fish were not more fecund than the younger ones of the same size.

As has been found for other fish species (Bagenal, 1978), the present study confirms that the absolute fecundity of hake and red pandora increases with increasing length, weight and age, suggesting that it would be suitable to examine in detail these variables and their relationship to fecundity. The small difference of the correlation coefficient between the fecundity for both studied species vs. length, weight or age, shows that fecundity can he expressed in terms of length, weight, as well as age. Generally, an exponential relationship exists between fecundity and the above parameters, although, in some other fish, the relationship has been found to be linear. In this study, the exponential relationship was found to fit better our data, even though, in a previous fecundity study on hake stocks of the Greek Seas (Tsimenidis and Papaconstantinou, 1985) a linear relationship without logarithmic transformation between fecundity and length, weight or age was applied.

The fecundity of hake and red pandora taken in the Saronikos and Patraikos Gulfs respectively was found to vary at a rate proportional to the length at a power of about 3.5 with regression coefficients between 3.52 and 0.001. These values of the exponent are generally in the middle part of the range of the values 3 to 5 reported by other authors for other species. Values between 3 and 4 have been reported by Raitt (1933) for North Sea haddock, by Botros (1962) for Baltic cod, by May (1967) for cod off eastern Newfoundland, while values between 4 and 5 have been reported by Powles (1953) for the Gulf of St. Lawrence cod and by Hodder (1963) for Grand bank haddock.

Comparisons of the correlation coefficients of the relationships of fecundity to length, weight and age separately indicate that fecundity is slightly better correlated with weight than with length or age. Lehman (1953) noted that for the Hudson river shad data, the correlation between fecundity and age was better ($r = 0.98$) than for fecundity and length or weight. This might be a peculiarity of the species. However, length measurements are usually more easily and more accurately obtained during field sampling than weight and age and with the rather insignificant difference between the correlation coefficients, the egg production of hake and red pandora may be considered to be adequately described by fecundity-length relationship of the form used in the present analysis. May (1967) reviewed the results of fecundity work on several species (cod, herring, long rough dab), which showed that, for most practical purposes, variation in fecundity is satisfactorily explained in terms of length alone. Raitt and Hall (1967) come to the same conclusion in their work on the Atlantic redfish.

REFERENCES

Bagenal, T. B. 1978. Aspects of fish fecundity. *In* S. D. Gerking (Editor), Ecology of Freswater fish Production. Blackwell Scientific Publication, Oxford, pp. 75—101.

Botros, G. A. 1962. Die fruchtbarkeit des dorsches (*Gadus morhua* L.) in der westlichen Ostsee und Westnorweigische Gewassern. Kiel. Meeresforch., 18: 67—70.

Clark, F. N. 1934. Maturity of the California sardine (*Sardina caerulea*) determined by ova diameter measurements. California Div. Fish and game Fish. Bull., 42, 49 pp.

D'Ancona, U. 1949. Sul diferanziamento della gonade e l'inversione sessuale degli Sparidi. Arch. Oceanogr. Limnol., 6: 97—193.

D'Ancona, U. 1956. Inversion spontanees et experimentales dans les gonades des Teleosteens. Annee Biol., Ser. 3, 32: 89—99.

Hodder, V. M. 1963. Fecundity of Grand Bank haddock. J. Fish. Res. Bd. Canada, 20: 1465—1487.

Lehman, B. A. 1953. Fecundity of Hudson River shad. U. S. Fish and Wildlife Serv., Res. Rept., 33: 1—8.

May, A. W. 1967. Fecundity of Atlantic cod. J. Fish. Res. Bd. Canada, 24: 1531—1551.

Morse, N. W. 1980. Maturity, spawning and fecundity of Atlantic croaker, *Micropogonias undulatus*, occurring north of Cape Hatteras, North Carolina. Fish. Bull., 78: 190—195.

Nikolsky, G. V. 1969. Theory of fish population dynamics. Oliver and Boyd, Edinburgh, 323 p.

Nikolsky, G. V. 1976. The ecology of fishes. Academic Press. New York—London, 352 p.

Powles, P. M. 1958. Studies on reproduction and feeding of Atlantic cod (*Gadus callarias* L.) in the southwestern Gulf of St. Lawrence. J. Fish. Res. Bd. Canada, 15: 1383—1402.

Prabhu, M. S. 1956. Maturation of intra-ovarian eggs and spawning periodicites in some fishes. Indian J. Fish., 3: 59—90.

Raitt, D. S. 1933. The fecundity of the haddock. Fish. Bd. Scot. Sci. Invest., 1: 1—40.

Raitt, D. S. and W. B. Hall. 1967. On the fecundity of the redfish *Sebastes marinus* (L). J. Cons., 31: 237—245.

Simpson, A. C. 1951. The fecundity of the haddock. Fish. Invest., Ser. 2, 17: 1—27.

Tsimenidis, N. and C. Papaconstantinou. 1985. A preliminary study of the fecundity of the hake (*Merluccius merluccius* L., 1758) in the Greek Seas. Inv. Pesq. 49: 55—59.

Tsimenidis, N., C. Papaconstantinou and C. Daulas 1978. On the biology of hake (*Merluccius merluccius*) in the Greek Seas. Thalassographica, 2: 27—50 (in Greek)

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FEKUNDITET OSLIĆA (*MERLUCCIUS MERLUCCIUS L.*) I ARBUNA (*PAGELLUS ERYTHRINUS* L.) IZ GRČKIH VODA

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KRATKI SADRŽAJ

Fekunditet oslića (*Merluccius merluccius* L.) i arbuna (*Pagellus erythrinus* L.) ispitan je na 55 primjeraka oslića i 27 primjeraka arbuna. Nije utvrđena značajna korelacija između veličine jaja i veličine ribe. Promjer zrelih oocita kretao se u rasponu od 0.45 do 0.80 mm kod oslića i od 0.35 do 0.60 mm kod arbuna. Fekunditet se kretao u rasponu od 24 000 do 296 300 zrelih jaja oslića i od 22 000 do 362 000 zrelih jaja kod arbuna. Fekunditet je rastao eksponencijalno s dužinom, težinom i starošću obe vrste riba. Korelacija između fekunditeta i dužine te između fekunditeta i težine nešto je bolja od korelacije između fekunditeta i starosti.