

Population biology of red mullet (*Mullus barbatus* L.) from the Ionian Sea

Biologie de la population du rouget (Mullus barbatus L.) dans la mer Ionienne

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ABSTRACT

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Aspects of *Mullus barbatus* population biology in the Ionian Sea (Mediterranean Sea) are reported. A total of 19,116 specimens were collected during six trawl surveys carried out from 1990 to 1993. The stock was mainly distributed at depths of less than 50 m in spring while it was generally located at greater depths in autumn. Reproduction was mostly observed during May and June. The Von Bertalanffy growth equation parameters were determined by otolith readings: $L_{\infty} = 245$ mm; $k = 0.27$; $t_0 = -1.85$ for females and $L_{\infty} = 224$ mm; $k = 0.28$; $t_0 = -1.98$ for males. The overall growth performance, assessed by means of the Munro phi prime test, identified the stock as being characteristic of the central-eastern Mediterranean. Total mortality rate (Z) was 1.59. Adopted natural mortality rate (M) was 0.41. On the basis of the estimates of population parameters, the results of the preliminary assessment, obtained by applying the yield per recruit model, indicated overfishing of the *Mullus barbatus* stock in the Ionian Sea.

RÉSUMÉ

Tursi A, A. Matarrese, G. D'Onghia, L. Sion, 1994 - [Biologie de la population du rouget (*Mullus barbatus* L.) dans la mer Ionienne]. Mar. Life, 4 (2) :

Dans ce travail, les auteurs analysent quelques aspects de la biologie de la population de *Mullus barbatus* vivant dans la mer Ionienne (mer Méditerranée). Les analyses ont été effectuées sur un total de 19 116 exemplaires échantillonnés au cours de six campagnes expérimentales de chalutage effectuées de 1990 à 1993. Le stock de cette espèce est principalement distribué jusqu'à 50 m de profondeur au printemps, tandis qu'il est plus profond pendant l'automne. La reproduction a été surtout observée pendant mai et juin. Les paramètres de la fonction de croissance de Von Bertalanffy ont été déterminés à travers la lecture des otolithes : pour les femelles : $L_{\infty} = 245$ mm ; $k = 0,27$; $t_0 = -1,85$; pour les mâles : $L_{\infty} = 224$ mm ; $k = 0,28$; $t_0 = -1,98$. La "valeur de croissance globale", évaluée à travers le "Munro phi prime test", a identifié un stock typique de la Méditerranée moyenne orientale. La mortalité totale (Z) est 1.59 et la mortalité naturelle (M) adoptée est de 0,41. En acceptant l'estimation des paramètres de la population, à travers le modèle de rendement par recrue, on a relevé un état de surpêche pour le stock de *Mullus barbatus* de la mer Ionienne.

INTRODUCTION

Although the aim of population dynamics studies is the "unit stock" it is at present very difficult to define the limits of a fish population because

a stock can have a very wide distribution range, especially if it belongs to a migrant species. However if a species shows little migratory behaviour and inhabits a circumscribed basin, despite the dispersal of eggs and larvae by means of currents in the mari-

ne environment, the stock can be considered, according to Sparre *et al.* (1989), to be "a group of organisms of one species having the same stock parameters and inhabiting a particular geographical area".

The stock parameters, such as growth and mortality, are indicators of genetic, physiological and environmental features (Pitcher, Hart, 1982) and fishing pressure is one of these (Levi *et al.*, 1991). There are therefore some background conditions (biological, geographical, economic, etc.) which can offer a rough preliminary estimate of the limits of a stock (Levi, Andreoli, 1989).

The red mullet (*Mullus barbatus*) in the Ionian Sea (Southern Italy), from Cape S. Maria di Leuca (Lecce) to Cape Spartivento (Reggio Calabria), lives in an area bounded by the Apulian and Calabrian coasts and the very deep waters of the central Gulf of Taranto (Figure 1). It is a little mobile species, whose range is within the continental shelf, with its own spawning areas and subject to particularly intensive fishing pressure in the Ionian Sea (D'Onghia *et al.*, 1989; Ribecco, D'Onghia, 1994).

In addition to these background aspects, features such as the distribution, reproduction, growth parameters and mortality coefficient of *Mullus barbatus* from the Ionian Sea (Southern Italy) are reported in this paper with the aim of increasing our knowledge of the population biology of the species in this area.

MATERIAL AND METHOD

The investigated area is situated between Cape Otranto (Lecce) and Cape Spartivento (Reggio Calabria) to a depth of 650 m; it is approximately 3,238 square miles in area.

The trawl surveys took place in the following periods: 1) September-October 1990; 2) April-May 1991; 3) October-November 1991; 4) May-June 1992; 5) November 1992; 6) May 1993.

A professional 50 t gross tonnage motor-powered fishing boat, with a 200 Hp engine, was used. It was equipped with nylon otter-trawl nets with 40 mm stretched mesh in the cod-end.

The experimental sampling design adopted, for biological and statistical reasons (Fogarty, 1985), was random-stratified, with the examined area subdivided into 5 depth strata: I = 10-50 m; II = 50-100 m; III = 100-200 m; IV = 200-400 m; V = 400-650 m. Each haul, carried out between dawn and dusk, lasted 2 hours. An average of 24 hauls were carried out for each survey. The number of hauls, carried out at each depth, was proportional to the surface area of the depth stratum (Doubleday, 1980; Levi & Andreoli, 1989).

For each sampled specimen the following parameters were recorded: length (mm), weight (g), sex and maturity stage of gonads according to the scale proposed by Nikolsky (1963). Six stages were considered: I) immature; II) maturing (beginning);

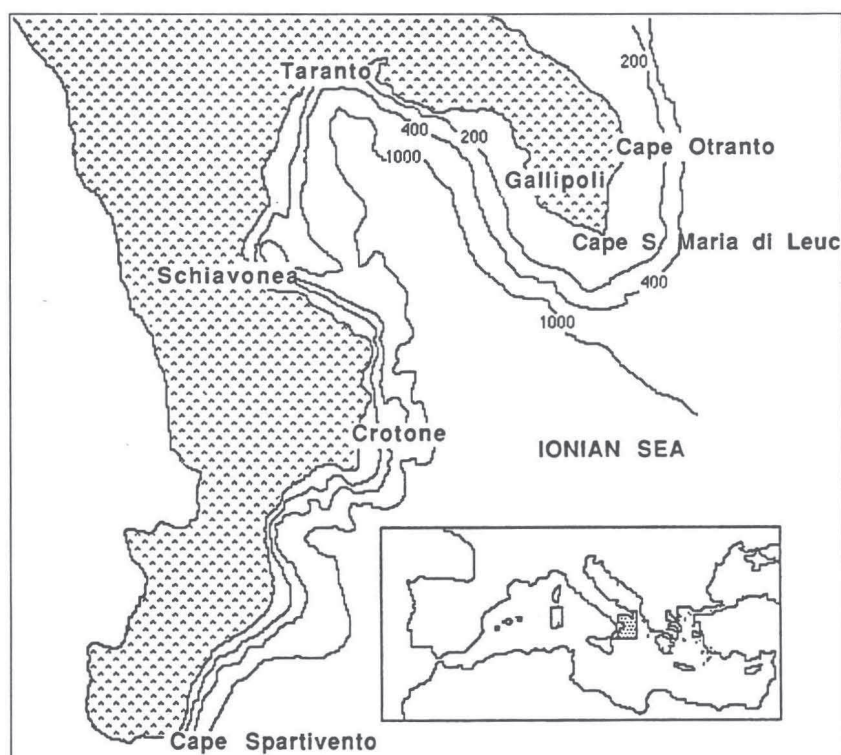


Figure 1 - Map of the investigated area in the Ionian Sea./Sites étudiés en mer Ionienne.

III) maturing (advanced); IV) mature; V) reproductive; VI) spent.

On a subsample of 300 specimens both otoliths (sagittae) were removed and preserved in glycerin. Readings were taken against a black background in reflected light. Age was designated according to Williams & Bedford (1973).

The parameters of the Von Bertalanffy growth equation were estimated according to the Ford-Walford method as reported by Pauly (1983).

The total mortality rate (Z) was determined by applying the length-converted catch curve (Ricker, 1975) using the ELEFAN program (Gayanilo *et al.*, 1988) while the natural mortality rate (M) was computed by the two relations:

$$\log M = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log k + 0.4634 \log T \text{ (Pauly, 1980)}$$

$$\log M = 0.7359 - 0.1140 \log L_{\infty} + 0.5222 \log k - 0.5830 \log T \text{ (Djabali et al., 1993)},$$

where: k is the annual growth coefficient, L_{∞} the asymptotic length (cm) and T the mean annual temperature of the sea water ($^{\circ}\text{C}$). This latter parameter has been taken as 14°C (Robinson, Golnaraghi, 1992).

The natural mortality rate (M) was also estimated by the method of Chen, Watanabe (1989) for which:

$$M(t, t + \Delta) = 1/\Delta \ln [e^{k(t+\Delta)} - e^{kt_0}] / [e^{kt} - e^{kt_0}]$$

where: t and $(t + \Delta)$ are the beginning and the end of the stable mortality phase ($t = 0$; $t + \Delta = 10$).

The state of the stock was assessed by means of the yield per recruit model of Beverton, Holt (1957) as simplified by Sparre *et al.* (1989).

RESULTS

Distribution of the stock

Mullus barbatus was mainly caught along the west coast of the Ionian Sea, because a large part of the bottoms, down to 100 m of depth, between Taranto and Cape S. Maria di Leuca are not trawlable owing to the presence of rocks. The stock was exclusively found on the continental shelf, that is above 150 m of depth. Females and males presented the same distribution pattern on the bathymetric gradient, despite a change in *sex ratio*, as reported below (Figure 2). More specifically, apart from November 1992, the majority of individuals, of both sexes, were fished between 50 and 100 m in Autumn and within the first depth stratum (< 50 m) in spring. This finding is consistent with those of other authors (Scaccini, 1947 a, 1947 b; Bougis, 1952; Piccinetti, 1968, 1971; Ardiczone, 1982; Ardiczone, Pelusi, 1983; Orsi Relini, Arnaldi, 1986; A.A.V.V., 1988; D'Ongchia *et al.*, 1989; Levi, 1991), namely that the species migrates to shallow waters during the spawning season and then goes back to the deeper grounds after reproduction. The new generation reaches the bottom during summer and

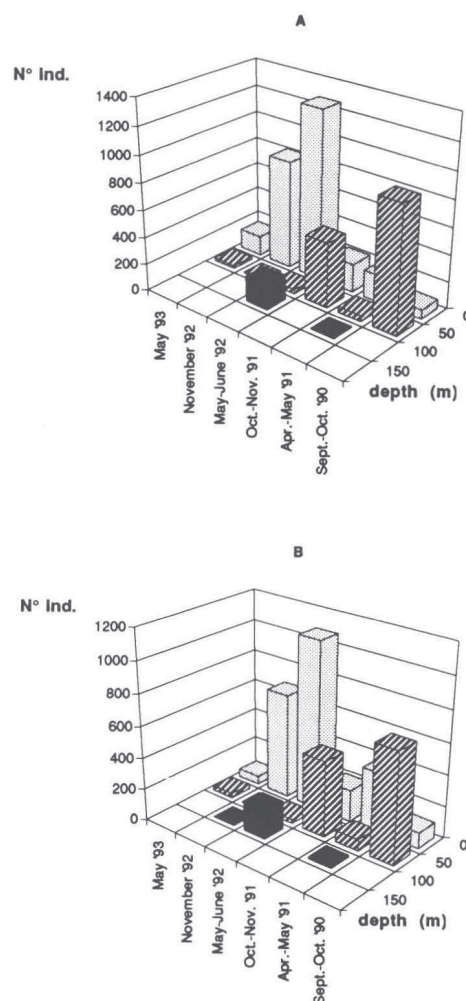


Figure 2 - Bathymetric distribution of individuals, females (A) and males (B), of *Mullus barbatus* caught in the Ionian Sea from September-October 1990 to May 1993./ *Distribution bathymétrique d'individus, femelles (A) et mâles (B) de Mullus barbatus en mer ionienne, de septembre-octobre 1990 à mai 1993.*

is mainly concentrated in shallow waters. Then the recruits, as they grow, join the adult stock on bottoms deeper than 40-50 m at the beginning of autumn.

The remarkable occurrence of small individuals, of both sexes, at depths down to 50 m, recorded in November 1992, may be due to a delay in recruitment in the investigated area.

The number of individuals at depths greater than 100 m was generally very low.

Length frequency distribution

The length frequency distributions relative to all individuals sampled in the area (No.=19,116) are presented in Figure 3. Although the minimum and maximum lengths ranged from 68 to 236 mm,

very few individuals longer than 190 mm were found in the area. The length-frequency polygons were gaussian in shape for all the surveys with the exception of September-October 1990 for which the size distribution was somewhat bimodal.

The average lengths computed for spring surveys were greater than those for autumn surveys (Table I). The difference observed between the sizes in the two seasons was statistically significant ($t = 3.736$; d.f. = 4; $P = 0.020$). In fact, the smallest individuals (< 100 mm), produced by the spring-summer reproduction of the species, were exclusively fished in autumn.

The modal component of 90-100 mm recorded in September-October 1990 reached the size class of 120-130 mm after about six months, namely in April-May 1991. The abundance of this latter modal group was abruptly reduced in the successive autumn (October-November 1991) because of the high fishing pressure occurring in the Gulf of Taranto, mainly during summer and early autumn (D'Onghia *et al.*, 1989).

The size frequency distribution by sex, presented in Figure 4, gives a more accurate indication of the presence of more modal groups in the stock, mainly during the autumn surveys. The modal pro-

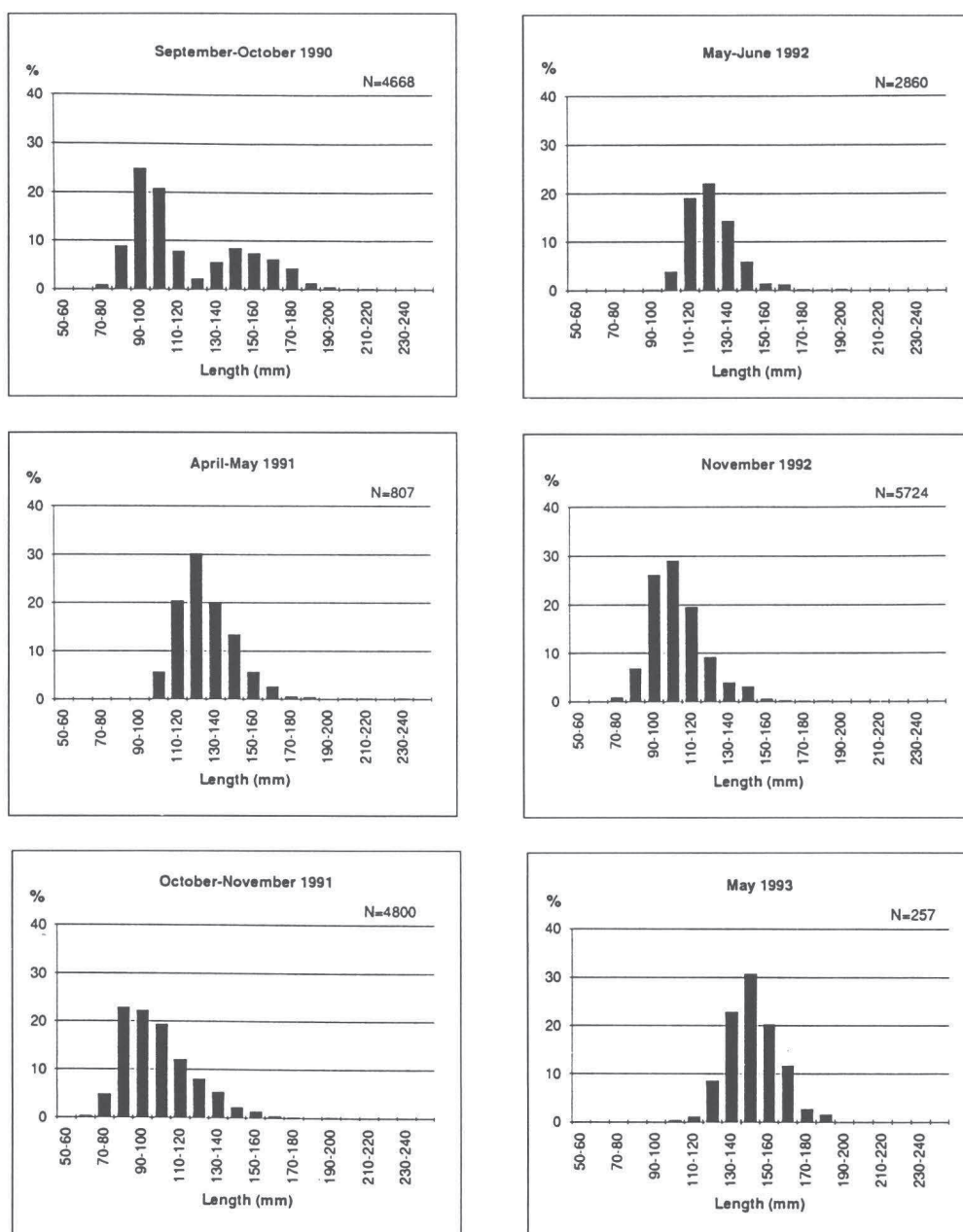


Figure 3 - Length frequency distribution of individuals of *Mullus barbatus* caught in the Ionian Sea from 1990 to 1993. / Pourcentage de la répartition des classes de taille des individus de *Mullus barbatus* capturés en mer ionienne entre 1990 et 1993.

Table I - Total number and average total length (T.L.), with standard deviation (s.d.), of individuals of *Mullus barbatus* caught in the Ionian Sea, from September-October 1990 to May 1993./ *Nombre total et moyenne générale des tailles (T.L.), avec l'écart-type (s.d.), des individus de Mullus barbatus entre septembre-octobre 1990 et mai 1993.*

Autumn			Spring		
Survey	N° Ind.	T.L. \pm s.d	Survey	N° Ind.	T.L. \pm s.d
September-October 1990	4668	120.49 \pm 29.29	April-May 1991	807	132.02 \pm 15.67
October-November 1991	4800	104.16 \pm 18.61	May-June 1992	2860	132.01 \pm 14.31
November 1992	5724	109.07 \pm 15.60	May 1993	257	146.63 \pm 13.61

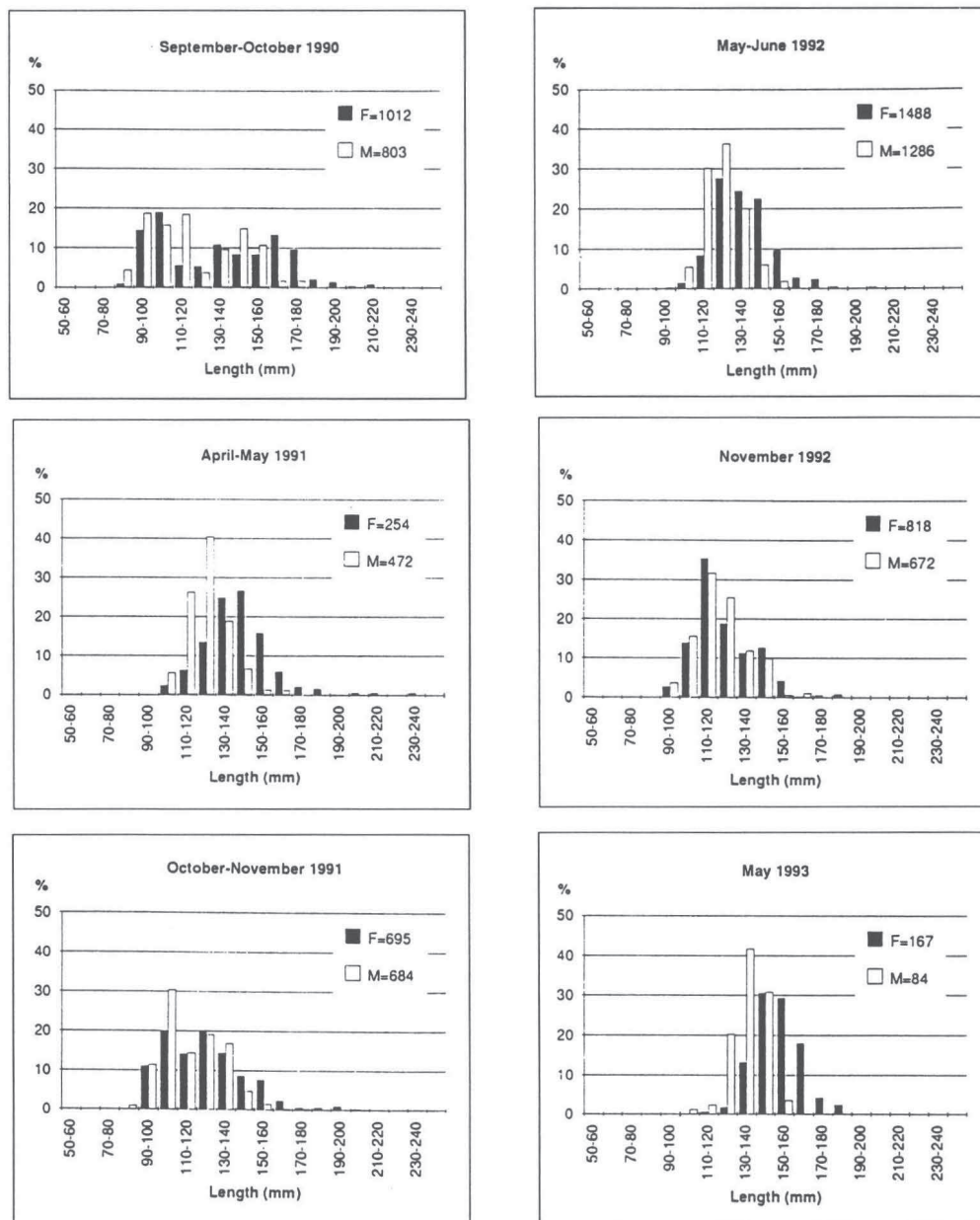


Figure 4 - Length frequency distribution by sex of *Mullus barbatus* caught in the Ionian Sea from 1990 to 1993./ *Pourcentage de répartition des classes de taille par sexe de Mullus barbatus capturés en mer Ionienne entre 1990 et 1993.*

Table II - Total number and average total length (T.L.), with standard deviation (s.d.), of females and males of *Mullus barbatus* examined from September-October 1990 to May 1993 in the Ionian Sea. / *Nombre total et moyenne générale (T.L.) avec l'écart-type (s.d.) des femelles et des mâles de Mullus barbatus entre septembre-octobre 1990 et mai 1993, en mer Ionienne.*

Survey	Females		Males	
	Nº. individuals	T.L. ± s.d.	Nº. individuals	T.L. ± s.d.
September-October 1990	1012	135.50±29.95	803	122.34±23.34
April-May 1991	254	143.89±17.61	472	126.82±10.77
October-November 1991	695	124.39±20.11	694	117.25±15.49
May-June 1992	1488	137.88±15.00	1286	126.01±10.04
November 1992	818	125.76±17.34	672	122.68±14.22
May 1993	167	152.21±12.28	84	136.40±9.02

Table III - Number of individuals (N) (f=female; m=male) and sex-ratio (f/m) of *Mullus barbatus* arranged by trawl survey and bathymetric stratum. / *Nombre d'individus (N) (f = femelle ; m = mâle) et sex-ratio (f/m) de Mullus barbatus dans les prélèvements de chalut en fonction des strates bathymétriques.*

Bathymetric stratum	Sept.-Oct. '90		April-May '91		Oct.-Nov. '91		May-June '92		November '92		May '93	
	f	m	f	m	f	m	f	m	f	m	f	m
0-50 (m) N f/m	72	102	201	384	211	201	1265	1077	813	670	146	54
	0.71		0.52		1.05		1.17		1.21		2.70	
50-100 (m) N f/m	940	701	47	75	484	483	33	26	4	2	21	30
	1.34		0.63		1.00		1.27		-		0.70	
100-150 (m) N f/m	-	-	6	12	-	-	189	183	-	-	-	-
	-		-		-		1.03		-		-	

Table IV - Percentage of maturity stage of gonad of *Mullus barbatus* caught in the Ionian Sea, from September-October 1990 to May 1993. / *Pourcentage du stade de maturité de la gonade chez Mullus barbatus capturé en mer Ionienne, entre septembre-octobre 1990 et mai 1993.*

Maturity stage of gonad	Surveys											
	Sept.-Oct. '90		April-May '91		Oct.-Nov. '91		May-June '92		November '92		May '93	
	f	m	f	m	f	m	f	m	f	m	f	m
	N=1012	N=803	N=254	N=472	N=695	M=694	N=1488	N=1286	N=818	N=672	N=167	N=84
I	4.55	17.56	5.12	5.30	10.50	10.09	0.07	-	0.12	2.08	-	-
II	71.94	59.03	21.65	41.31	84.03	67.69	1.14	8.01	94.13	91.82	0.60	-
III	6.72	5.98	51.18	35.38	5.47	21.05	20.77	46.35	5.75	5.65	1.20	9.53
IV	-	7.85	22.05	17.59	-	1.17	49.72	36.16	-	0.45	7.78	28.57
V	15.91	9.58	-	0.21	-	-	28.23	9.48	-	-	88.02	61.90
VI	0.88	-	-	0.21	-	-	0.07	-	-	-	2.40	-
tot.	100	100	100	100	100	100	100	100	100	100	100	100

gression of the first size class was faster in females than in males. Indeed, the average length of females was greater than that of males in each period (Table 2) and the difference was statistically significant ($t = 2.237$; d.f. = 10; $P = 0.049$).

Maximum total lengths in females and males were 236 mm and 204 mm respectively.

Sex ratio and reproduction

The chi-square test indicated a highly significant difference ($P < 0.01$) from the expected 1:1 ratio both for each investigated depth stratum and for the whole research period (1990-1993) (Table 3).

With regard to reproduction, percentages of gonad maturity stages are reported in Table 4. Although mature specimens (stage IV and V) were mostly found during spring, the percentage values observed in May-June '92 and particularly in May '93 were higher than those recorded in April-May '91. All these mature specimens were generally caught at depths down to 50 m on trawlable bottoms along the Calabrian coast.

Moreover, in autumn, a significant percenta-

ge of spawning individuals of both sexes was recorded in September-October '90 whereas only a few mature males (IV stage) were fished in October-November '91 (1.17 %) and November '92 (0.45 %). However, individuals presenting stage II gonads were always most abundant in the stock during autumn (over 78 % on average).

The smallest mature specimen measured 110 mm in females and 100 mm in males. The lengths at first maturity (50%) in females and males were 135 mm and 125 mm respectively.

Growth and mortality

A length-age key was obtained from the otolith readings and the average length at each age was as follows:

Age (Year)	1	2	3	4	5
Av. Length (mm)					
Females	133 ± 8	158 ± 17	184 ± 24	190 ± 26	208 ± 19
Av. Length (mm)					
Males	127 ± 10	150 ± 8	168 ± 2	177 ± 14	

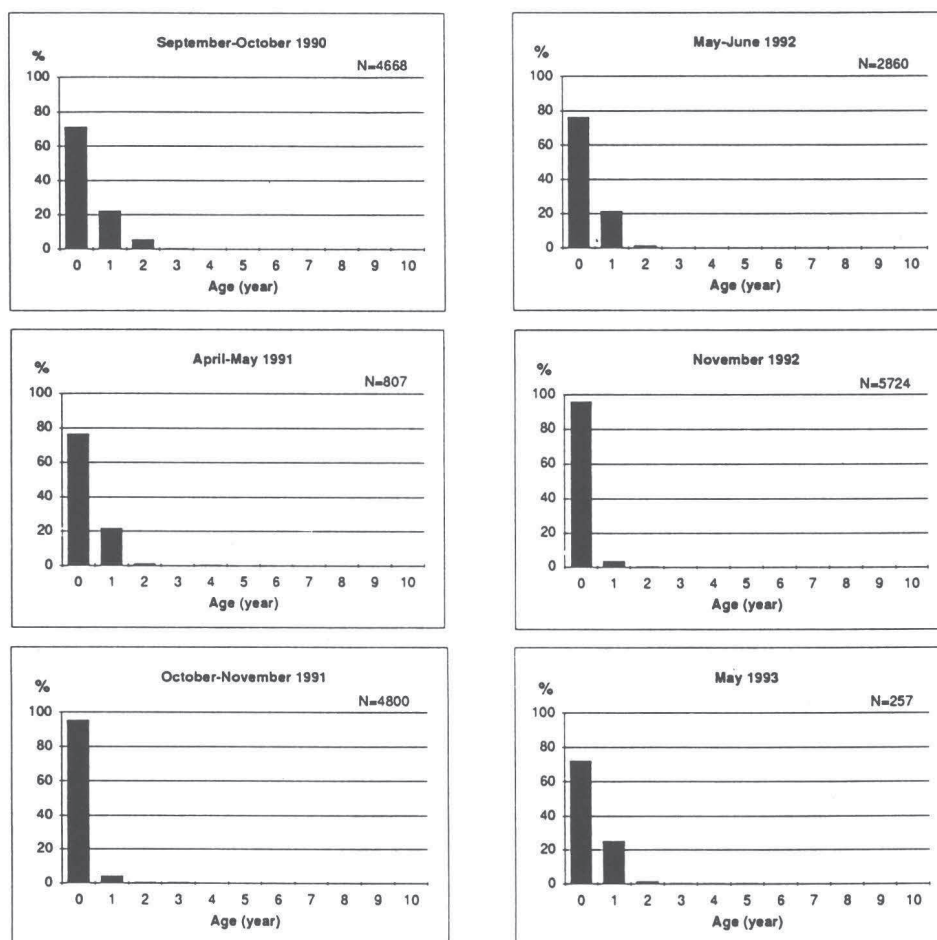


Figure 5 - Age frequency distribution of individuals of *Mullus barbatus* caught in the Ionian Sea from 1990 to 1993. / Distribution des fréquences d'âge de *Mullus barbatus* capturé en mer Ionienne entre 1990 et 1993.

These average lengths were used to compute the following values with the Von Bertalanffy equation:

Combined sexes	$L_t = 252 [1 - e^{-0.26(t+1.71)}]$
Females	$L_t = 245 [1 - e^{-0.27(t+1.85)}]$
Males	$L_t = 224 [1 - e^{-0.28(t+1.98)}]$

The age structure of the sampled population (Figure 5) was determined from these growth parameters confirming the fact that the stock was mainly made up of the year's young, above all during autumn.

The natural mortality rates (M) calculated with different methods are as follows:

	M (Pauly)	M (Djabali, et al.)	M (Chen, Watanabe)
Combined sexes	0.55	0.41	0.36
Females	0.57	0.42	0.36
Males	0.60	0.43	0.36

Total mortality rate (Z) estimated using the ELEFAN program was 1.59 during the period of research (1990-1993). The average fishing mortality rate (F), accepting M = 0.41, was 1.18.

DISCUSSION AND CONCLUSION

Although data on the *Mullus barbatus* population have been collected during only two seasons of the year, many of the phenomena observed in the course of the study are consistent with the biology and population dynamics of this species in other areas of the Mediterranean (Scaccini, 1947 a, 1947 b; Ananiadis, 1950; Bougis, 1952; Larraneta, Rodriguez-Roda, 1956; Bougis, Muzinic, 1958; Hasshem, 1973; De Ranieri, 1979; Togulga, 1979; Gharbi, Ktari, 1981; Papaconstantinou et al., 1981; GFCM, 1982; Livadas, 1984; Andaloro, Prestipino-Giarritta, 1985; Arneri & Jukic, 1986; Orsi Relini, Arnaldi, 1986; Papaconstantinou et al., 1986; A.A.V.V., 1988; Levi, 1991; Levi et al., 1993).

In particular, reproduction occurs during May-June and is probably prolonged during summer until the beginning of autumn. Shallow waters along the Calabrian coast represent the spawning and nursery areas of the investigated stock. Red mullet in the Ionian Sea reach sexual maturity at the beginning of the second year in females and at the end of the first year in males.

The change in the 1:1 sex ratio, observed mainly during April-May 1991, is probably due to the segregation of sexes during spawning. As previously reported (Scaccini, 1947 b; Ardizzone, Pelusi, 1983; D'Onghia et al., 1989), females are generally distributed in very shallow waters, less than 10 m in depth, which were not investigated during this study. Often, the low representation of males in the older age groups of samples, as shown in May 1993, may indicate a differential mortality among the sexes. Despite the different numbers of females and males found during the study, they exhibited the same distribution pattern on the bathymetric gradient.

Although the method used to determine Von Bertalanffy parameters does not estimate the variability of L_{∞} and k, the growth equation obtained fits the data rather satisfactorily and is in agreement with the modal progression of length observed at least for the first two age groups (Figure 6). Furthermore, testing the reliability of growth parameters by means of Munro's phi prime test (Pauly, Munro, 1984) the Φ' values are:

Φ' Combined sexes = 5.11;

Φ' Females = 5.09;

Φ' Males = 4.95

These values of Φ' are within the range of estimates made using growth parameters of red mullet determined in other Mediterranean areas, such as in the Adriatic Sea (5.93) (Scaccini, 1947 b), in the Aegean Sea (4.89) (Ananiadis, 1950), in the Castellon Sea (5.01) (Larraneta, Rodriguez-Roda, 1956) and in the Sicilian Channel (4.91) (Andaloro, Prestipino-Giarritta, 1985), (4.77) (Levi et al., 1991).

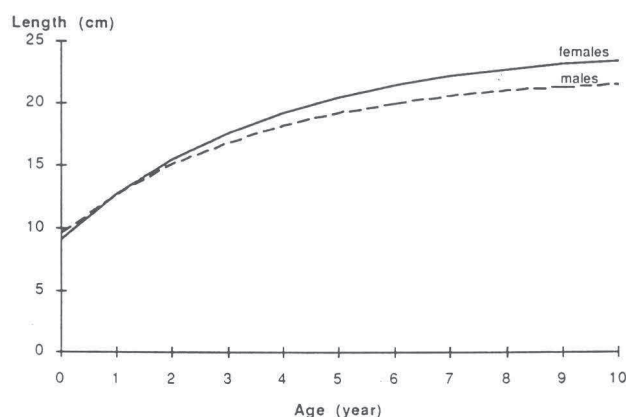


Figure 6 - Von Bertalanffy growth curves for *Mullus barbatus* from the Ionian Sea. / Courbe de croissance de Von Bertalanffy chez *Mullus barbatus* en mer Ionienne.

Although different Φ' values can also be obtained from other growth parameters of the species, for example 3.21 in the Aegean Sea (Papaconstantinou *et al.*, 1981) and in Cypriot waters (Livadas, 1984), the "overall growth performance" observed for the stock in the Ionian Sea is in agreement with that shown by an "Eastern Aggregate" (a curve resulting from a set for growth equations of eastern Mediterranean stocks) computed by Levi *et al.*, 1991. These authors proposed the use of Φ' as a concise way of assessing the influence of geographical location on the shape of the growth curve. In this respect, the present Φ' value of red mullet from the Ionian Sea can preliminarily identify the stock as being characteristic of the middle-eastern Mediterranean in the context of the west-east geographical locations of various stock analyzed by Levi *et al.* (1991) for the whole basin.

Besides these mathematical considerations, small differences between various growth parameters for the same species may be due to the method used to estimate them and may also be the result of sampling gear selectivity, levels of exploitation or other ecological factors. The low rate of growth observed in the Catalan Sea is probably related to overfishing, as reported by Morales-Nin (1986). The higher value of k in the Ionian Sea could be a consequence of remarkable recruitment observed in this basin.

Concerning the mortality, the estimate of natural mortality by means of the Pauly (1980) formula seems rather high, whereas M as determined by means of Djabali *et al.*, 1993 and Chen, Watanabe (1989), despite the two different methods of computation, are of the same order of magnitude and are just a little higher or in accordance with what is known about the natural mortality of red mullet in the Mediterranean Sea. The different methods used to estimate M all depend to a varying degree on the k value, with that of Chen, Watanabe (1989) being most affected; therefore M is highly dependent on k . However, for all estimated values of natural mortality rate the ratio M/k lies in the range of 1.5 to 2.5 according to Beverton, Holt (1959). The total mortality rate (Z) is within the range of estimates recently made in the Italian basins (AA. VV., 1994).

Accepting $M = 0.41$, a preliminary state of stock can be obtained by computing the ratio of exploitation (E) which in this case comes out as 0.74. This E value indicates preliminarily overfishing of the stock in the Ionian Sea, on the basis of an optimum exploitation of $E = 0.5$ (Gulland, 1969).

To provide further information of the state of the stock, on the basis of the available estimates, the Beverton, Holt yield per recruit model has been applied. Growth parameters for the whole stock, $M = 0.41$ and lengths at first capture $L_c = 84$ mm, for 30 mm mesh size, and $L_c = 112$ mm, for 40 mm mesh size, (GFCM, 1982; Jukic, Piccinetti, 1988) have been employed in the model.

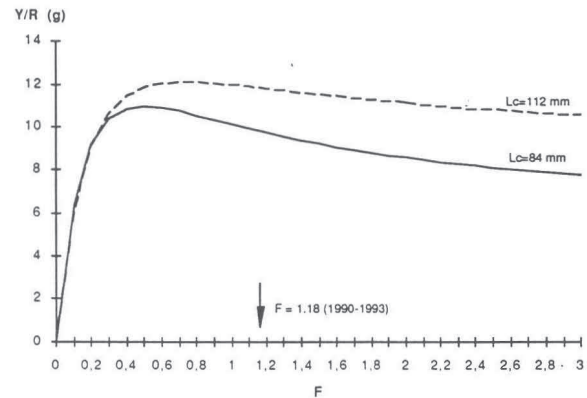


Figure 7 - Yield per recruit curve related to fishing mortality rate (F) of *Mullus barbatus* stock for $L_c = 84$ mm and $L_c = 112$ mm in the Ionian Sea. / Courbe de recrutement en relation avec le taux de mortalité (F) chez *Mullus barbatus* pour $L_c = 84$ mm et $L_c = 112$ mm en mer Ionienne.

The yield per recruit curves relative to F are shown in Figure 7. The maximum Y/R are 10.5g and 12g for the lengths at first capture used respectively. A condition of overfishing can be confirmed for the stock of red mullet in the Ionian Sea (Ribecco, D'Onghia, 1994), particularly if the mesh size generally used in the Ionian fisheries (30 mm) is considered.

Although the particularly high fishing pressure in the area contributes to this result, many factors influence this assessment, e.g. sampling techniques, growth parameters and mortality rate estimation methods, etc. Furthermore, part of the *Mullus barbatus* population in the investigated area is most probably common to the East side of the basin, between Taranto and Cape S. Maria di Leuca, where there are no trawlable bottoms and where there are other spawning and nursery grounds of the species. Part of the population could be common to some neighbouring areas, such as the Southern Adriatic Sea.

Consequently, on the basis of the information reported here, studies on the population genetics and ecology, or at least the distribution and dispersal of eggs and larvae of the species, should be encouraged so that population limits and management units can be accurately determined.

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