

LIFE HISTORY TRAITS OF *HOPLOSTETHUS MEDITERRANEUS* (PISCES: BERYCIFORMES) FROM THE NORTH-WESTERN IONIAN SEA (MEDITERRANEAN SEA)

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The fish *Hoplostethus mediterraneus* is a bycatch of the deep-water trawling in the north-western Ionian Sea. Data on its life history traits were collected during twelve trawl surveys carried out at two month intervals, between August 1993 and July 1995.

A vertical distribution according to size was observed for this species. The year's young were recruited mainly during the spring–summer period. Sex-ratio changed by size with females larger than males. Mature specimens were found mainly between May and November with a reproductive peak during late summer.

Seasonal growth was detected in the otoliths; the maximum ages of 11 and 10 y were observed in females and males respectively. Von Bertalanffy growth parameters for the whole population were: $L_{\infty}=287.08$ mm, $k=0.127$ y, $t_0=-2.131$. No significant differences were detected between the growth patterns of the sexes. Overall growth performance depicted through size-distribution analysis was not significantly different from that obtained by otolith reading.

Estimates of natural mortality rate for the whole population ranged from 0.14 to 0.20. Population structure, growth pattern, age at first maturity and low natural mortality rate indicate a life history mainly constituted by k-strategy characters and regulated by density-dependent mechanisms.

INTRODUCTION

Our knowledge on the biology of silver roughy, *Hoplostethus mediterraneus* (Cuvier, 1829), comes mainly from the studies carried out in the eastern Atlantic (e.g. Maurin, 1968; Golovan, 1978; Marshall & Merrett, 1977; Merrett & Marshall, 1981; Mauchline & Gordon, 1984; Gordon & Duncan, 1985, 1987) and mostly concerns its distribution, reproduction and feeding habits. With regard to this latter aspect *H. mediterraneus* is primarily a benthopelagic feeder for which natant decapods are the main prey (Marshall & Merrett, 1977; Merrett & Marshall, 1981; Gordon & Duncan, 1987). Although very little is known on the interaction of this fish with commercial species in the trophic web, the considerable dietary overlap with some abundant commercial species, such as *Merluccius merluccius* (Papaconstantinou & Caragitsou, 1987) and *Aristeus antennatus* (Cartes & Sardà, 1989), suggests competition. However, to define the role of such competition it is necessary to consider whether *H. mediterraneus* is a selective or opportunistic feeder and if, in relation to the abundance of the potential prey organisms in the benthopelagic zone, the demand of the species for food items in common with other species is in excess of supply.

There is no specific indication that silver roughy is a prey of commercial species while the commercial fish *Micromesistius poutassou* was found in its diet (Gordon & Duncan, 1987) and commercial shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus* in the diet of *H. atlanticus* (Rosecchi et al., 1988).

The growth pattern of *H. mediterraneus* in the western Indian ocean (Madagascar mountain ridge), the south-western Pacific (Norfolk mountain ridge) and from the continental slope of Ireland is reported by Kotlyar (1980).

This fish occurs throughout the Mediterranean and is frequently caught as a bycatch species during bathyal trawling. Its biology has been described by Cau & Deiana (1982) and some preliminary information (aspects of reproduction and growth) are reported by D'Onghia et al. (1995). The latter authors had difficulties in ageing the species through simple otolith reading without any validation techniques or detailed studies of its biology or life cycle but nevertheless reported an asymptotic growth pattern as far as the tenth year-class.

Data on the vertical distribution of *H. mediterraneus* in the Mediterranean is biased towards areas where the continental slope is most suitable for commercial trawling. In fact, the deepest bathymetric limit of 800 m known for the species (Tortonese, 1970; Cau & Deiana, 1982) corresponds to the maximum depth investigated by trawl, at least in Italian waters.

Considering the wider vertical distribution of *H. mediterraneus* observed in the north-eastern Atlantic (Golovan, 1978; Merrett & Marshall, 1981; Gordon & Duncan, 1987) trawling in the Mediterranean probably does not fish deep enough to provide information on the whole population of the species. Moreover, as for many deep-sea fish, there is a lack of knowledge of the early life history stages, from egg to recruit.

Despite these difficulties, trawling currently represents the main technique for recovering specimens of silver roughy mainly because this kind of fishing allows the investigation of the depth range in which the highest abundance of the species has been observed (Merrett & Marshall, 1981; Gordon & Duncan, 1987). Studies of deep-sea commercial species started by the Department of Zoology, University of Bari provided the opportunity to collect data on its life history, within the fishable population. Particularly, this study on *H. mediterraneus* was carried out in the context of an EC project related to deep-water shrimps, *Aristaeomorpha foliacea* and *Aristeus antennatus*, which represent an important commercial resource in the north-western Ionian Sea. Many non-commercial species, including silver roughy, are abundant in the range where deep-water shrimps are exploited (Matarrese et al., 1996). Information on space-time distribution, reproduction and population parameters of *H. mediterraneus* was collected in order to provide a contribution to the knowledge of the life style and phenology of this fish within deep sea communities.

MATERIALS AND METHODS

A total of 3078 specimens of *Hoplostethus mediterraneus* were collected during 12 trawl surveys carried out, at two month intervals, between August 1993 and July 1995.

A commercial 75 tons gross tonnage motor powered vessel was chartered, with a 360 Hp engine and equipped with nylon otter trawl net, with stretched mesh of 40 mm. The horizontal and vertical net opening, measured by means of the SCANMAR sonar system and depending on various factors (depth, warp length, towing speed, etc.), ranged respectively from 21.71 to 25.09 m and from 0.80 to 0.73 m (Fiorentini et al., 1994). The vessel speed, measured by using Global Positioning System, was maintained at 2.5–2.8 knots.

The sampling design adopted was random. The number of hauls carried out during each survey was 17 on average. The hauls lasted ~2 h each. Temperature and salinity were measured in the water column, from the surface to the bottom, for each haul, by means of a sound set-up on the headline of the net.

Abundance of *H. mediterraneus* was expressed as density (N per 1000 m²) and biomass (kg per 1000 m²). Since the distribution of the abundance was very skewed the data were adjusted for a normal distribution by means of logarithmic transformation of the numbers and weights of each haul. This was carried out in order to compare the mean values with confidence intervals between depths and seasons.

Total length (mm), sex and maturity stage of gonad were recorded for each specimen. This latter character was recorded according to Nikolsky (1963) considering the following maturity stages: (I) virgin; (II) resting (immature); (III) maturing; (IV) mature; (V) running ripe; (VI) spent. The sex of the virgin gonad (stage I) was indistinguishable in the very small specimens.

Sex ratio by size and depth was computed after pooling data from the 12 surveys. Statistical differences between changes in the number of males and females by surveys and depths were determined using the G-test (Sokal & Rohlf, 1969). The G-test is a goodness-of-fit test which can be used to test the agreement of observed frequencies with those expected on the basis of a hypothesis. In the case of the sex ratio the null hypothesis was $H_0 = F:M = 1:1$.

G-statistics follow the χ^2 distribution fairly closely making it possible to test sub hypotheses in the context of more complicated designs where it is simpler to carry out than the χ^2 -test (Möller, 1979).

The size at first maturity (size at which 50% of the fish in the population had ripe gonads) for both females and males was determined, for the pooled data, from the logistic curve showing the percentage of mature specimens (stages IV and V) by size class.

In the laboratory, total body weight and gonad weight were recorded for a sample of 664 specimens. The gonadosomatic index was computed as follows:

$$\text{Gonadosomatic index (GSI)} = \left(\frac{\text{gonad weight}}{\text{total body weight}} \right) \times 100 \quad (1)$$

Both sagittae were removed from 900 specimens. Since otoliths are somewhat thick at each size, the smallest sagittae were read as whole while the sagittae belonging to the specimens >150 mm were ground to obtain the best reading. Sagittae from specimens >200 mm after inclusion in resin were sectioned longitudinally as the major axis. Otoliths were placed in a black dish with glycerin to improve reading. The

hyaline zones were treated as *annuli* and counted under a stereoscope using reflected light. Otoliths were read at least twice. If agreement was not reached after several readings, the otoliths in question were excluded from the growth estimate. Approximately 50% of otoliths of all sizes were rejected. The number of annual rings were conventionally designated with 1,2,3,, n while the start of the following year's growth (incomplete annual ring) was indicated with the plus sign 1+, 2+, 3+,, n+ (Nikolsky, 1963).

The length/weight relationship was computed for each sex according to the power curve function transformed into a straight line equation using natural logarithms:

$$\ln \text{ weight} = \ln a + b \ln \text{ total length} \quad (2)$$

The linear regression equations for the two sexes were compared statistically using the Chow-test (Koutsoyiannis, 1977). This test verifies if there is a significant difference between both the slope (b) and the intersect (a) of two regression lines estimated from two different samples.

The von Bertalanffy (1934) function was adopted to model the growth pattern of *Hoplostethus mediterraneus*. The least square method was applied to the age/length relationship implemented in the LFSA program (Sparre, 1987), excluding the first year class because it was not completely recruited. In particular, the program estimates the growth parameters L_{∞} , k and t_0 in the ordinary von Bertalanffy (1934) model:

$$L_i = L_{\infty} [1 - e^{-k(t_i - t_0)}] \quad (3)$$

from pairs of observed age (t_i) and length (L_i) where $i = 1, 2, 3, \dots, n$.

The program uses a non-linear least squares procedure which estimates the growth parameters in such a way that the sum of the squares of the deviations between the model and the observations is minimized. The procedure is iterative and requires an initial guess of the parameters. It stops when two consecutive iterations give the same result. The results of the parameter estimation are given together with the estimated standard deviation and confidence intervals (Sparre, 1987; Sparre et al., 1989).

Since the von Bertalanffy growth parameters L_{∞} and k are inversely correlated, the growth performance index (Φ) (Munro & Pauly, 1983) was computed ($\Phi = \log k + 2 \log L_{\infty}$) in order to compare growth rates in the two sexes. Moreover, comparison between length-at-age of the two sexes was also carried out through *t*-testing.

Validation of the growth pattern was carried out by means of length-frequency distribution analysis through the Bhattacharya (1967) method using the same program. Length-at-age from von Bertalanffy parameters obtained by this method and otolith readings were compared by means of the *t*-test.

Natural mortality rate (M) was calculated, for each sex separately, according to some methods which consider the growth pattern, the environmental temperature and gonad maturity linked to this population parameter often impossible to obtain by direct measurement. In particular, the Taylor (1960) method was employed considering that the growth parameter (k) is related to the longevity of the species and longevity is related to mortality. Generally, fast growing species have a high natural mortality while species which grow slowly have a low natural mortality (Sparre et al., 1989).

Furthermore, as most biological processes increase at higher temperatures, Pauly (1980) considered the natural mortality to be related to the environmental temperature and proposed an empirical formula which gives M as a function of k , L_{∞} and the environmental temperature where the species lives.

Concerning sexual maturity, Gunderson & Dygert (1988) found a relationship between natural mortality rate and the ratio of gonad weight to body weight considering that fish with a high mortality may compensate by producing a larger quantity of eggs.

RESULTS

Environmental parameters

Neither temperature nor salinity differed significantly at depths greater than 150–200 m in the north-western Ionian Sea. Temperature only changed with the seasons from the surface to ~ 200 m. It varied in the uppermost layers from 12.8°C (January 1995) to 27.5°C (September 1994). Beyond 200 m in depth there were homeothermic conditions in the water column of ~ 13.5 – 13.8°C throughout the year (Figure 1).

Salinity also showed significant variability in the uppermost 200 m but below this depth values were steady at $\sim 37.6\text{‰}$.

The sampled population

Density and biomass

Hoplostethus mediterraneus was caught in 167 of the 204 hauls carried out in the area. The majority of the hauls (101) had a numerical abundance < 10 specimens and a number > 100 was caught only during six tows carried out between 429 and 569 m.

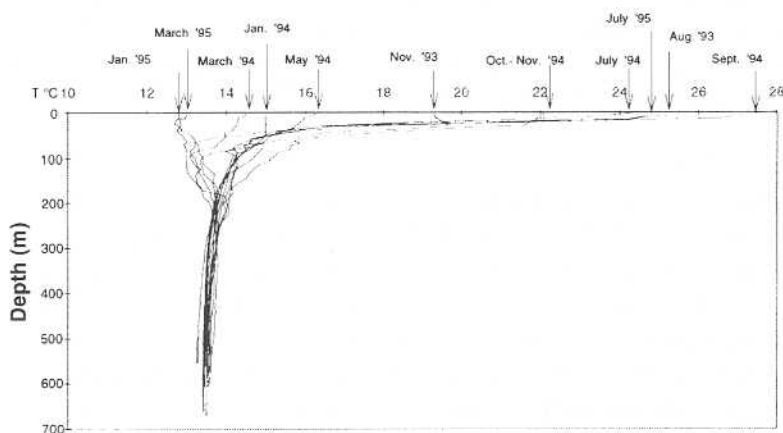


Figure 1. Sea-water temperature from the surface to the bottoms measured in the north-western Ionian Sea from 1993 to 1995.

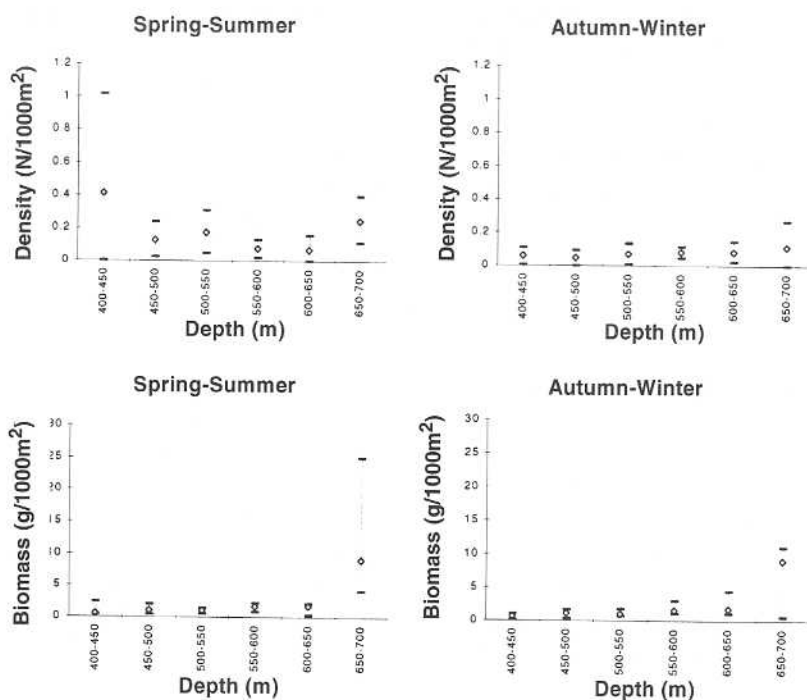


Figure 2. Density (N per 1000 m²) and biomass (g per 1000 m²) by depth and season of *Hoplostethus mediterraneus* caught in the north-western Ionian Sea from 1993 to 1995 (confidence limits at 95% are indicated for each average value).

Density (N per 1000 m²) and biomass (g per 1000 m²) by depth and season are presented in Figure 2. The density was slightly higher during the spring-summer period than autumn-winter. An inverse trend occurred between seasons: the highest value was observed at the uppermost layer in spring-summer while a slight increase in the mean density according to depth was detected in autumn-winter.

Concerning the biomass, the highest average value was shown at the lowest depths in both the spring-summer and autumn-winter periods.

Size and sex composition

The length-frequency distributions examined monthly (Figure 3) showed a common pattern in all but the first three surveys in which very few unsexed individuals were collected. A wide range of sizes was observed in both sexes, with the largest females and males measuring 260 and 233 mm respectively. A multimodal structure was found with two more abundant size groups: the first represented by the unsexed individuals < 90 mm and the second consisted generally of specimens with lengths between 120 and 180 mm. The modal progression of the unsexed specimens from January to July was the same in both years.

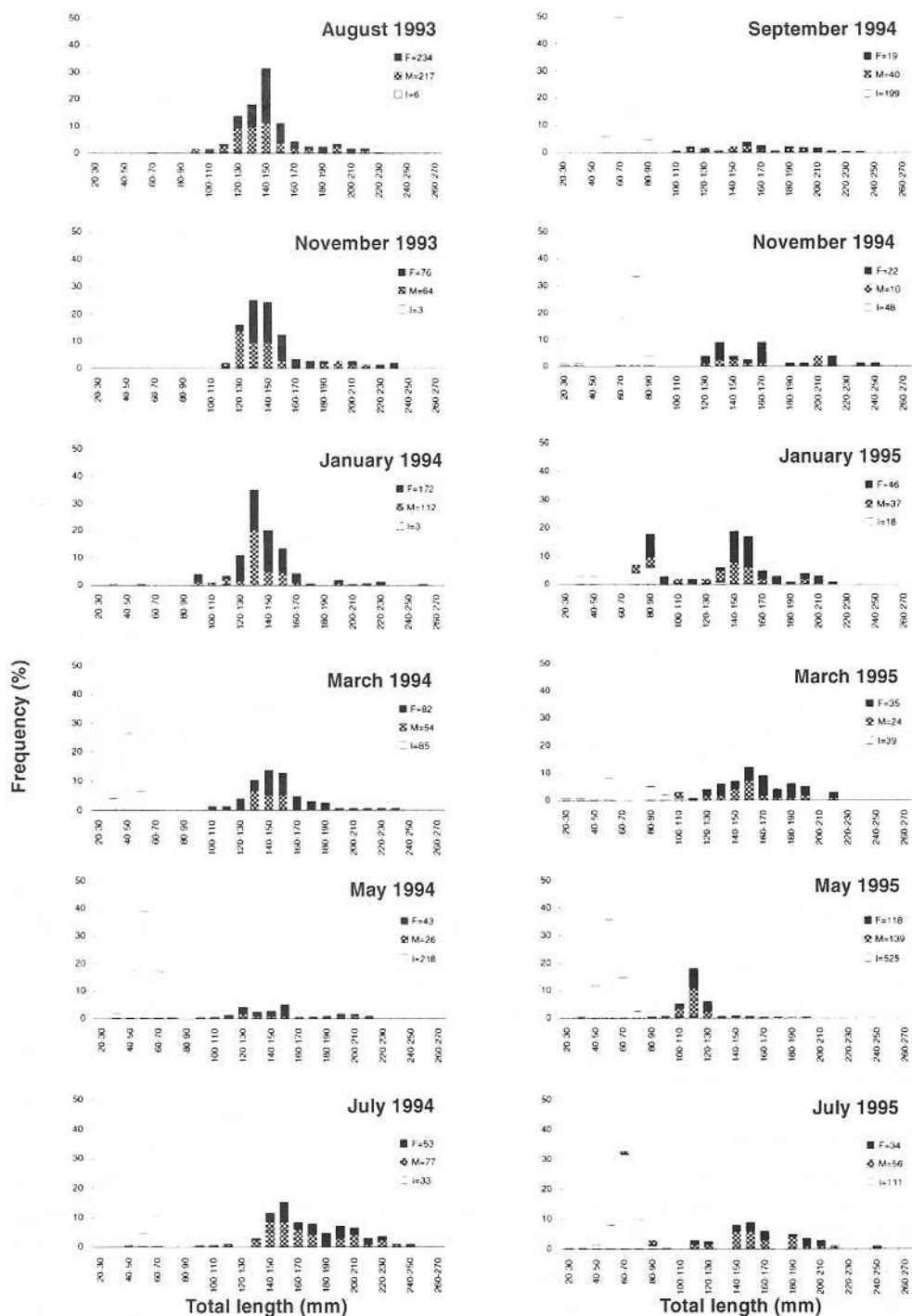


Figure 3. Length–frequency distributions of *Hoplostethus mediterraneus* (F, females; M, males; I, unsexed specimens) caught in the north-western Ionian Sea from 1993 to 1995.

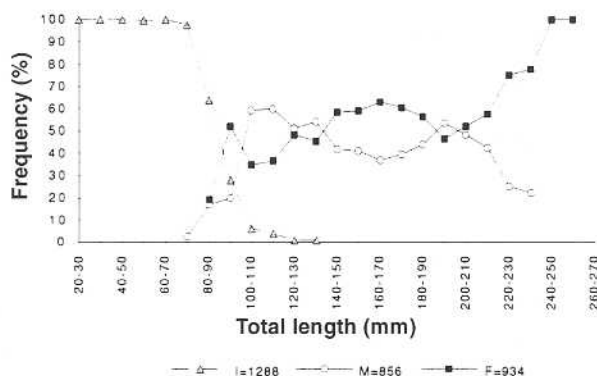


Figure 4. Percentage by length of *Hoplostethus mediterraneus* (F, females; M, males; I, unsexed specimens) caught in the north-western Ionian Sea from 1993 to 1995.

All specimens < 80 mm were sexually indeterminate. Males generally predominated in the size classes between 100 and 140 mm while females were generally more abundant over this latter length (Figure 4). The sex ratio within the whole research period was significantly different from the 1:1 theoretical value ($G_{11}=47.98$; $P < 0.01$).

Size and sex distribution

Considering the vertical distribution of the sampled population, an increase in size with depth was observed (Figure 5). The smallest individuals were mainly caught at the shallower depths and larger individuals almost exclusively at depths > 500 m.

Sex ratio by depth oscillated ~50%. No significant departure from the 1:1 theoretical value was detected at any one depth stratum ($P > 0.05$).

Reproduction

Maturity and spawning season

Mature specimens as well as maturing and immature ones were found throughout the year. Although variations were observed throughout the research programme, the highest percentage of mature individuals (stage IV and V) were caught during summer and mainly in July (Figure 6). The main spawning season was May–September in 1994 and it appeared to be somewhat delayed during 1995. Females with spent ovaries were found during November 1993 and January 1995 while spent males were never detected.

The trend of the gonadosomatic index in the females had its main peaks during July of both years and the highest values during the summer–autumn months (Figure 7). On the contrary, no significant variations were observed in the gonadosomatic index of the males.

The relationship between the gonadosomatic index and length of both sexes is shown in Figure 8. Gonadosomatic index (GSI) values increase with size, but the rate of the increment is not continuous throughout, especially in males. After an initial

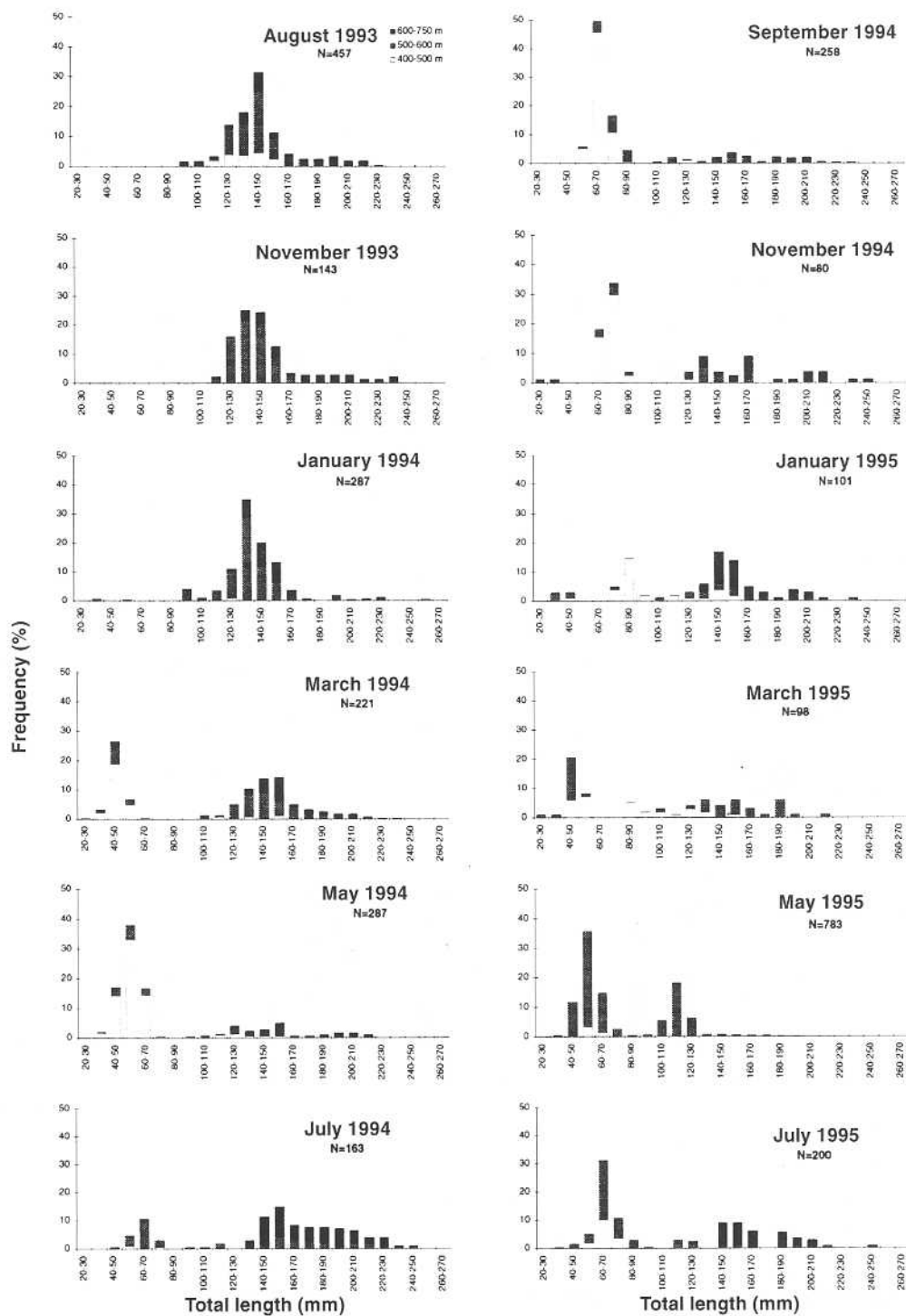


Figure 5. Length–frequency distributions by depth of *Hoplostethus mediterraneus* caught in the north-western Ionian Sea from 1993 to 1995.

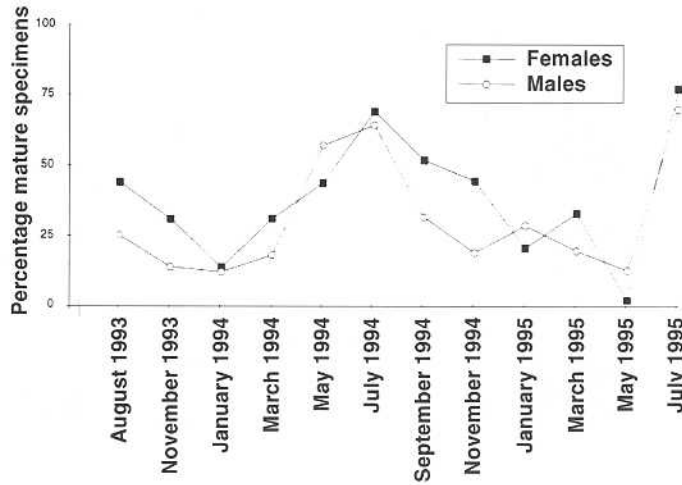


Figure 6. Percentage of mature specimens of *Hoplostethus mediterraneus* caught in the north-western Ionian Sea from 1993 to 1995.

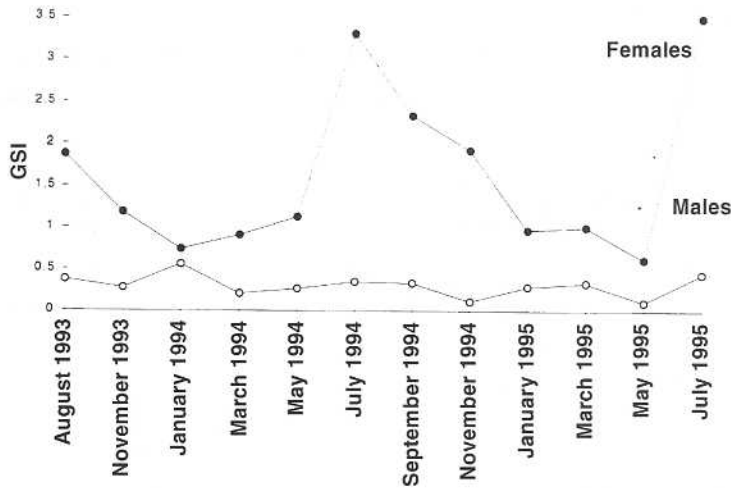


Figure 7. Changes in gonadosomatic index (GSI) with surveys in *Hoplostethus mediterraneus* caught in the north-western Ionian Sea from 1993 to 1995.

phase where the values are rather low for the immature specimens there is quite a rapid increase beyond a size of 120 mm in both sexes. While in males the highest GSI values can be observed for sizes ~140–160 mm, in females a high individual heterogeneity characterizes the whole process.

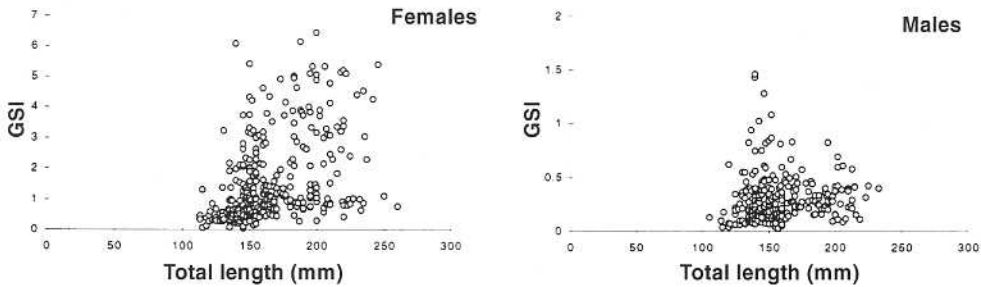


Figure 8. Gonadosomatic index by length of *Hoplostethus mediterraneus* females and males, caught in the north-western Ionian Sea from 1993 to 1995.

Size at first maturity

The smallest mature females and males measured 125 and 115 mm respectively. The size at attainment of 50% maturity was 165 mm in females and 155 mm in males. While at sizes >190 mm almost all females were mature, at lengths >170 mm great changes in the percentage of mature males were observed confirming the trend shown in the relationship between the gonadosomatic index and length.

Although mature specimens of both sexes were found across the whole bathymetric range investigated, the highest concentration was at the deepest bottoms.

Growth

Growth in weight

The length–weight relationship was computed for the total length expressed in millimetres and weight in grams. The parameters of the relationship, intersect (a) and slope (b) with standard deviation, were as follows:

Females	$a=10^{-6} \times 4.4 \pm 1.31$	$b=3.16 \pm 0.14$
Males	$a=10^{-6} \times 5.2 \pm 0.67$	$b=3.05 \pm 0.13$

The Chow-test revealed significant differences ($F^*=173.67$; $P<0.01$) between the length–weight relationship of the two sexes.

Growth in length

Otoliths of *Hoplostethus mediterraneus* were very irregular in shape, not comparable with any geometric form and had a heartshaped *nucleus*. Whole otoliths exhibited alternating opaque and hyaline bands. Several thin and not clearly distinct hyaline zones are formed around otolith *primordius* during the first year of life. The last one of these is generally best developed and may be distinguished as a complete hyaline zone. It is formed mainly during the spring–summer season and is probably indicative of habitat changes.

Table 1. Age-length key for the total population of *Hoplostethus mediterraneus* caught in the north-western Ionian Sea from 1993 to 1995.

	0	0+	1	1+	2	2+	3	3+	4	4+	5	5+	6	6+	7	7+	8	8+	9	9+	10	10+	11
240-250																	1					1	1
230-240																	1		1			1	1
220-230																		3				1	1
210-220																			7			1	1
200-210													1	1	2	2	6		7				
190-200							2				2	1	1	1	1	2	8	2	4				
180-190							6				6	4	8	1	1	4	4						
170-180							3				3	5	6			2	1						
160-170							12		2	5	12	1											
150-160							3		17	6	4												
140-150						9	14		24	4													
130-140						18	13		8														
120-130						3	7																
110-120						1	14																
100-110						12	6																
90-100						4																	
80-90						5	1																
70-80						28																	
60-70						1																	
50-60	2	25	1																				
40-50	13	3																					
30-40	23																						
20-30	8																						
	1																						
N	47	28	33	36	24	14	37	31	51	20	26	10	16	6	12	8	20	2	15	-	-	3	3
Mean	46.3	63.2	73.9	98.1	121.0	129.0	143.5	150.3	156.6	164.5	169.9	178.0	180.6	182.8	194.9	197.5	204.9	206.2	213.3	-	-	242.0	246.0
SD	8.71	3.71	4.00	14.55	8.35	6.06	6.62	6.49	7.71	5.94	12.20	9.40	7.91	4.76	3.73	9.80	9.50	6.24	8.35	-	-	11.06	13.20

Table 2. *Von Bertalanffy growth parameters of Hoplostethus mediterraneus obtained from the age-length key.*

Parameters	Estimate (\pm SD)	Confidence limits
Combined sexes		
L_{∞} (mm)	287.08 \pm 10.106	267.27 - 306.88
k (y)	0.127 \pm 0.0115	0.104 - 0.149
t_0	-2.131 \pm 0.2204	-2.564 - -1.699
Females		
L_{∞} (mm)	296.14 \pm 17.780	261.29 - 330.99
k (y)	0.112 \pm 0.0166	0.079 - 0.144
t_0	-2.635 \pm 0.3905	-3.401 - -1.870
Males		
L_{∞} (mm)	270.48 \pm 14.691	241.68 - 299.27
k (y)	0.133 \pm 0.0188	0.096 - 0.170
t_0	-2.466 \pm 0.3383	-3.129 - -1.803

The age-length key obtained from 442 otoliths is reported in Table 1. Maximum age was 11 y in females and 10 y in males but these age classes were poorly represented in the sampled population. An asymptotic pattern of growth is evident from this key. Computation of von Bertalanffy growth parameters gave the following result shown in Table 2:

Although larger sizes and greater ages were observed in females than in males, the growth performance is somewhat superimposed between the sexes ($\Phi_{\text{females}}=3.992$; $\Phi_{\text{males}}=3.988$) and no significant difference ($P>0.05$) between length-at-age was observed (Figure 9).

The Bhattacharya method identified from three to seven size groups in the length-frequency distributions of the whole population. These were generally well-defined (Separation Index >2) even though some were scarcely represented ($N<20$). Apart from the survey of January 1995, no significant differences ($\chi^2<\text{critical values}$, $P>0.05$) were found between the expected and the observed length-frequency distributions.

The smallest representative size class was observed during March of both years (45.00 \pm 7.46 mm during 1994; 47.73 \pm 5.12 mm during 1995). The largest representative groups were found during July 1994 (225.38 \pm 6.60 mm) and November 1994 (210.00 \pm 9.54 mm). From the first recruitment pulse (March 1994) modal length increased from 45.00 \pm 7.46 mm to 52.72 \pm 7.13 mm (May), 63.19 \pm 7.71 mm (July), 69.43 \pm 7.72 mm (September), 72.15 \pm 6.08 mm (November), 83.80 \pm 5.88 mm (January 1995), 102.69 \pm 8.15 mm (March) and 115.32 \pm 8.15 mm (May) respectively.

Table 3. *Von Bertalanffy growth parameters of Hoplostethus mediterraneus obtained from the length-frequency distributions analysis.*

Parameters	Estimate	Confidence limits
L_{∞} (mm)	270.03	238.78-301.27
k (y)	0.226	0.175-0.277

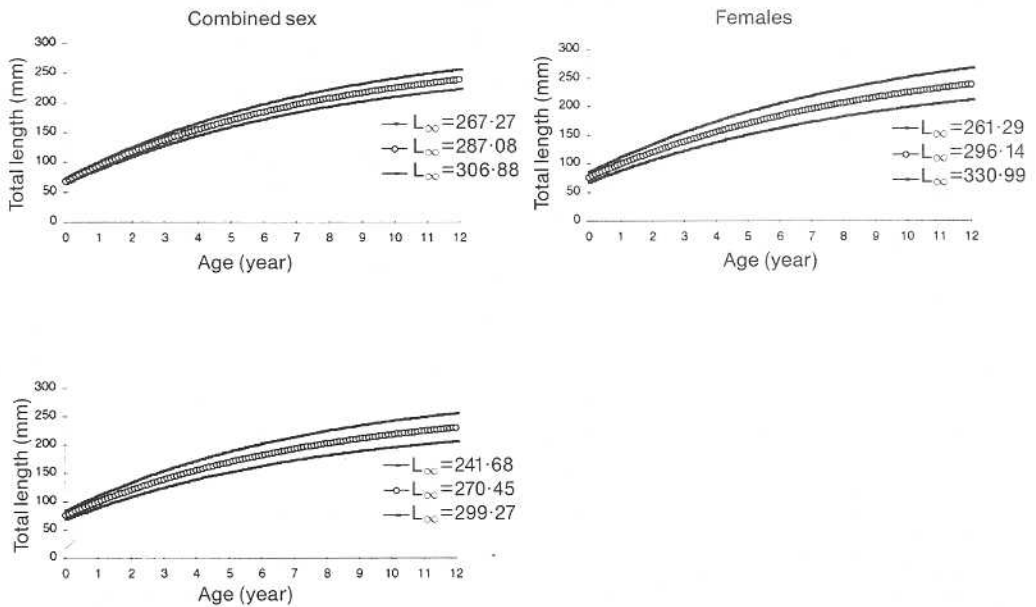


Figure 9. Estimated von Bertalanffy growth curves for *Hoplostethus mediterraneus* caught in the north-western Ionian Sea from 1993 to 1995.

Table 4. Natural mortality rate of *Hoplostethus mediterraneus* computed according to various methods.

Method	$M_{\text{combined sexes}}$	M_{females}	M_{males}
Taylor (1960)	0.14	0.12	0.15
Pauly (1980)	0.17	0.16	0.18
Gunderson & Dygert (1988)	0.20	0.19	0.21

Modal progression analysis throughout the several size groups identified in the length-frequency distributions produced the following estimate of the von Bertalanffy growth parameters presented in Table 3.

An estimate of $t_0 = -0.4$ was obtained from the empirical relationship reported by Pauly (1983). The growth performance index (Φ) was 4.217. There was no significant difference ($P > 0.05$) between length-at-age from von Bertalanffy parameters obtained by length-frequency analysis and age reading.

Mortality

The estimates of the annual natural mortality rate (M) were as follows:

According to the methods employed a maximum age of ~ 25 and 21 y was estimated for females and males respectively.

DISCUSSION AND CONCLUSIONS

Hoplostethus mediterraneus was caught with somewhat low density and biomass in the north-western Ionian Sea. Density was lower than that recorded by Merrett & Marshall (1981) off north-west Africa and comparable to that reported by Gordon & Duncan (1987) from the slope of Porcupine Sea Bight. The biomass was more than one order of magnitude smaller than that observed in the north-east Atlantic area (Gordon & Duncan, 1987) probably because of the different catching potential of the sampling gear used and the smaller size of the specimens found in the north-western Ionian Sea.

The highest density recorded in the uppermost depth during spring-summer was due to the recruitment to the fishing gear while the highest biomass found beyond 600 m in each season was in agreement with the distribution of the largest sizes at the greatest depths, known as the 'bigger-deeper' phenomenon (Polloni et al., 1979). This size-related depth segregation appears to conform to a population distribution pattern that would minimize intraspecific competition between size classes in order to optimize energy utilization through balanced partitioning of available resources (Werner, 1979; Rosecchi et al., 1988; Gage & Tyler, 1991).

The species displays, seasonally synchronized reproduction with spawning occurring in late summer as observed by Cau & Deiana (1982) in the western Mediterranean and Gordon & Duncan (1987) in the north-eastern Atlantic. Gonadosomatic index (GSI) data were also in agreement with these authors. The very slight variations in the male GSI could be a consequence of the fact that the morphological changes of the testes associated with maturation are much less pronounced than in females. Moreover, significant differences in the variations of GSI in the two sexes are due to the fact that females have the highest energetic investment in gonads. It is more costly to produce eggs which become larger than sperm.

The spawning as a discrete event occurring during late summer, was confirmed by discrete recruitment which, considering the mesh size used in the codend, becomes evident during the successive winter. Timing of spawning and recruitment was consistent over the two year study. Considering that the spawning peak is in late summer and that the smallest specimens (<30 mm) are recruited in November, an egg-larval phase lasting about three months can be supposed for the species. However, even smaller specimens could reach the bottom earlier but would not be sampled by the gear used in this study.

Considering the large egg sizes of *Hoplostethus mediterraneus* (Cau & Deiana, 1982; Gordon & Duncan, 1987) a surface distribution of the eggs can be assumed and may be of significance if hatching larvae utilize the plankton production of late summer (Cushing, 1981, 1982). Thus eggs and larvae could develop in waters where the seasonal thermocline is relatively stable, as observed for other deep sea species in the north-western Ionian Sea (Giovanardi et al., 1989). In fact, the temperature values recorded at the surface in this basin during August and November of both years were around 26 and 19°C respectively. In January the surface temperature was 15-16°C, however in this month the new generation has already reached the deep-water nursery grounds where the temperature is around 13.5°C throughout the year.

At the end of the first year the specimens attain a size of ~ 70 mm and are almost exclusively distributed at depths less than 500 m until the second year of life when they reach a size of ~ 115 – 120 mm.

The growth pattern of the species was in agreement with observations made by Kotlyar (1980). This author reported a maximum age of 5+ y in a female with standard length (SL) of 16.2 cm found on the Madagascar mountain ridge and an age of 4–9 y for 13 fish collected on the slope of Ireland, the sizes of which ranged between 13.7 and 19.8 cm (SL).

The growth proved faster than that preliminarily evaluated by D'Onghia et al. (1995). Even though a slight difference between the modes from Bhattacharya analysis and age-length key was shown, the parameters estimated by means of the two methods gave overlapping results. In other words, although some approximation occurred in the validation of the length-at-age by means of size-frequency distribution a high correspondence of the overall growth performance was observed in the two methods employed. Furthermore, the slight difference observed could be the consequence of the variability in the recruitment, individual growth, mortality and sampling errors in the length distribution of the various surveys.

Age at first maturity was around 4 y according to Kotlyar (1980).

Although the two sexes exhibited the same growth pattern, females appear to be longer-lived than males and thus to be subject to a lower natural mortality rate. However, our estimates of M were somewhat similar for females and males. Although from the estimates of the mortality rate by means of three methods rather similar values were obtained, the knowledge of this life history parameter requires additional studies related to the factors affecting it. Moreover, even though natural mortality rate is very simple to estimate with the method employed here it can be biased in relation to the estimation of growth parameters coming from an incomplete coverage of the whole population in the area, i.e. if the very large specimens are able to escape from the gear used or could be distributed at depths greater than those investigated during this research.

In the context of r - k selection theory the specific combinations of population parameters shown in silver roughy, can be identified as being characteristic of a k strategist (Adams, 1980; Jobling, 1995). The variability in abundance of the large size classes of both sexes in the sampled population could be the consequence of the fact that the bottom trawl is not very suitable for sampling this benthopelagic species which feeds in the water column (Merrett & Marshall, 1981; Macpherson, 1983; Gordon & Duncan, 1987). This means that the spawning stock in the area could be more abundant than that assessed by using this gear, and that the population could have a lower variability in size-class than that exhibited in size-frequency polygons.

Low variability in the year-class strengths would indicate that density-dependent mechanisms regulate cohort strength (Adams, 1980; Jobling, 1995). Density-dependent regulation operates upon the population in order to establish an equilibrium level of abundance and to lead towards population stability. So that, despite the expected fluctuations a population which contains many year-classes and several overlapping generations tends to buffer oscillations around the equilibrium size. *Hoplostethus mediterraneus* in the Ionian Sea is captured as a bycatch species

within the deep-water shrimp fishery presenting fairly stable catch levels (Matarrese et al., 1996). This is because the population comprises many age-classes and thus there should only be comparatively small changes in population size.

The r-k selection theory attempts to explain the relationship between life history strategy and the habitat a species occupies (Jobling, 1995). In the stable environment where *H. mediterraneus* lives mortality factors are predictable and thus the optimal strategy would be to produce offspring with good competitive and survival ability. In fact, large egg size appears to reduce instantaneous mortality in fish species (Ware, 1975). The information available on fecundity and egg sizes of *H. mediterraneus* (Cau & Deiana, 1982; Gordon & Duncan, 1987) and data collected on *H. atlanticus* (Pankhurst & Conroy, 1987; Pankhurst et al., 1987; Du Buit, 1995) indicate bestowal as a strategy more than high fecundity in fish belonging to this genus. Furthermore, studies on the feeding strategy of the genus (Merrett & Marshall, 1981; Macpherson, 1983; Mauchline & Gordon, 1984; Gordon & Duncan, 1987; Rosecchi et al., 1988) also indicate that the species are characterized by traits giving efficient exploitation of the resources in a stable environment. The long life span as well as the large sizes of the eggs and individuals upon which k selection operates lead the organisms to consider the environment to be even less variable (Begon, 1985).

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