Age, growth, mortality, reproduction, and feeding habits of the striped seabream, *Lithognathus mormyrus* (Pisces: Sparidae), in the coastal waters of the Thracian Sea, Greece*

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SUMMARY: Age, growth, mortality, reproduction and feeding habits were analysed for *Lithognathus mormyrus* collected in the coastal waters of the Thracian Sea from November 1997 to September 1999. Specimens ranged from 42 to 341 mm in total length. Weight increased with size allometrically (b = 3.242) for immature individuals and isometrically (b = 2.960) for males, females and intersexuals. Growth was described by the standard form of the von Bertalanffy growth equation and the estimated parameters were k = 0.21, t_0 = –0.996 and L_∞ = 309.4. Total and natural instantaneous rate of mortality was found to be Z = 0.79 year^{-1} and M = 0.61 year^{-1}. Sex inversion occurred mainly between 210 and 300 mm (4-9 age classes). Males reached sexual maturity at 162.1 mm (2.5 years) and females at 190.40 mm (3.6 years). The spawning period occurred from May to September, while the gamete emission peaked in June-August. Stomach content analysis revealed that *L. mormyrus* is a carnivorous species feeding on benthic invertebrates, mainly polychaeta and bivalve molluscs. Ontogenetic variation in the diet composition showed that while growing, the fish become more generalist feeders. We also found that in the summer season the fish become more selective feeders.

Keywords: *Lithognathus mormyrus*, northeastern Mediterranean, age, growth, mortality, reproduction, feeding.

RESUMEN: EDAD, CRECIMIENTO, MORTALIDAD, REPRODUCCIÓN Y ALIMENTACIÓN DE LA HERRERA, *LITHOGNATHUS MORMYRUS* (PISCES: SPARIDAE) EN LAS AGUAS COSTERAS DEL MAR DE TRÁCIA, GRECIA. – La edad, crecimiento, reproducción y alimentación de *Lithognathus mormyrus* capturados en aguas costeras del mar de Trácia entre noviembre 1997 y septiembre 1999 han sido analizadas. La talla total de los especímenes osciló entre 42 y 341 mm. El peso aumentó con la talla alométricamente (b=3.242) para los individuos inmaduros e isométricamente (b=2.960) para machos, hembras e intersexuales. El crecimiento ha sido descrito mediante la forma estándar de la ecuación de crecimiento de von Bertalanffy; los parámetros estimados han sido: k=0.21, t_0=–0.996 y L_∞=309.4. La tasa instantánea de mortalidad total y natural ha sido Z=0.79 año^{-1} y M=0.61 año^{-1}. La inversión de sexo tuvo lugar principalmente entre 210 y 300 mm (clases de edad 4-9). Los machos alcanzaron la madurez sexual a 162.1 mm (2.5 años) y las hembras a 190.4 mm (3.6 años). El período de puesta tuvo lugar entre mayo y septiembre, con un pico en junio-agosto. El análisis de contenidos estomacales reveló que *L. mormyrus* es una especie carnívora que se alimenta de invertebrados bentónicos, principalmente de poliquetos y moluscos bivalvos. La variación ontogenética en la composición de la dieta mostró que a lo largo del crecimiento los individuos devienen generalistas. Estacionalmente, se ha encontrado que en verano los individuos devienen más selectivos.

Palabras clave: herrera, *Lithognathus mormyrus*, Mediterráneo oriental, edad, crecimiento, mortalidad, reproducción, alimentación.

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INTRODUCTION

Lithognathus mormyrus (Linnaeus, 1758) is common in the Mediterranean Sea, the Atlantic Ocean from the Bay of Biscay to the Cape of Good Hope, the Red Sea and the south-western Indian Ocean. It is a demersal species that inhabits the rocky and sand-muddy bottoms and seagrass beds down to 80 m (Mediterranean) and 150 m (Atlantic) in depth. It is a gregarious species, entering exceptionally in coastal lagoons (Bauchot and Hureau, 1986; Suau 1970; Tortonese, 1975).

In the Mediterranean Sea, *L. mormyrus* is a highly prized species and an important catch for the coastal fishery. Along the coast of the Thracian Sea the species is caught mainly by trammel net and secondarily by other gear such as gill nets, beach seines and fyke nets. In the study area *L. mormyrus* is landed year-round with a peak in winter.

L. mormyrus is a protandric hermaphrodite fish (Bessau, 1990). Aspects of its reproduction, age and growth have been studied in the northern and middle Adriatic Sea (Kraljevic *et al*., 1995; Kraljevic *et al*., 1996), in eastern Spanish coastal waters (Suau, 1955, 1970) and in the central-east Atlantic (Lorenzo *et al*., 2002; Pajuelo *et al*., 2002). Its diet has been investigated in eastern Spanish coastal waters (Suau, 1970), in the western Adriatic Sea (Froglia, 1977) and in the northwestern coastal waters of Sicily (Badalamenti *et al.,* 1992). In Greek seas, the only published data concern its geographical distribution (Papacostantinou, 1988) and its length-weight relationship (Koutrakis and Tsikliras, 2003).

The aim of the present work is to investigate aspects of the life history and biology of *L. mormyrus* in the Thracian Sea coastal waters, including age, growth, mortality, reproduction and feeding habits, and to contribute to the optimisation of the species management.

MATERIAL AND METHODS

Study area and sampling

The biological data were collected within a programme on the artisanal fisheries in the Thracian Sea coastal zone, which was carried out from 1997 to 2000. Fish samples were collected at landing from trammel nets, gill nets, fyke nets, bottom long lines and beach seines catches. At landing site fish were stored in iceboxes and transferred to the laboratory, where they were weighed to the nearest 0.01 g and measured (total length) to the nearest mm. They where dissected and the alimentary tract and gonads were removed, weighed to the nearest 0.01 g and fixed in 10% neutral formalin. The gonads were examined macroscopically and sex and maturity stage were recorded. Sagittae otoliths were extracted for age determination, washed, dried and stored in paper envelopes. The whole sampling took place from November 1997 to September 1999 and resulted in the collection of 1688 individuals in total.

Age and growth

The length-weight relationship was calculated by the equation $W = a\ L^b$, where W is the total body weight (g), L is the total length (cm), a is a coefficient related to the body form and b is an exponent indicating isometric growth when equal to 3 (Anderson and Neumann, 1996; Wotton, 1990). The parameters a and b were estimated by linear regression on the transformed equation: $\log_{10}(W) = \log_{10}(a) + b\log_{10}(L)$. Differences of b-values between sexes were calculated by analysis of covariance (ANCOVA, Zar, 1999) and the hypothesis of isometric growth (b = 3) by *t*-test (Economou *et al.,* 1991).

For age determination 721 individuals (from 50 to 341 mm in total length) were chosen from October 1997 to February 1998 and from May 1998 to September 1998. The otoliths were examined under a binocular microscope using transmitted light in X15 enlargement on a dark background. The hyaline zones were treated as annuli and were counted. The number of annuli, radius length at each annulus and whole otolith radius length were recorded. Radii were measured on the nucleus-antirostrum ridge direction. Otoliths were read three times by a single examiner with an interval of two months between the readings. To improve the periodicity of annuli formation, the marginal increment ratio (MIR) for each specimen was computed according to the formula:

$$MIR = (O-r_n)/O$$

where O = otolith radius and r_n = radius of the most recent annulus. The mean of MIR and its standard error were computed for each month and age separately. Marginal increment analysis was performed only for the fifth and the sixth age-classes because of the lack of seasonal samples in the other age classes. Back calculation of length-at-age was estimated from the Whitney and Carlander equation

(Whitney and Carlander, 1956 in Francis, 1990), assuming that the body length-otolith length relationship is linear:

$$Li = [(c+dSi)/(c+dSc)]*Lc$$

where *Lc* is the length of the captured fish, *Sc* is the related otolith radius, *Li* and *Si* are the related lengths at the *i*-annulus formation and the relative radius at the same time. The parameters c (intercept) and d (slope) were derived from the regression line between the length and the related otolith radius.

Data on fish length and age estimated from the otolith readings were fitted to the standard form of the von Bertalanffy growth equation using a least square method applied to a non-linear fit:

$$L_t = L_\infty(1\text{-}\exp(-k(t\text{-}t_0)))$$

where L_t is the total length-at-age *t*, *K* is the growth rate coefficient, L_∞ the asymptotic length and t_0 the theoretical age at length 0.

Total mortality (*Z*) was estimated using the catch curve method applied to the samples fished with a trammel net (King, 1995). The natural mortality (*M*) was computed using Pauly's (1980) empirical equation based on the estimation of L_∞, *k* and the annual mean sea water surface temperature of 1998 in the study area (17.36°C, Sylaios, personal communication). Fishing mortality (*F*) was obtained by subtracting the natural mortality (*N*) from the total mortality (*Z*).

Sex maturity

Gonads collected during the whole sampling period were examined macroscopically. The sex was recorded and the stages of maturation were classified as follows (Nikolsky, 1963): I, immature; II, quiescent; III, ripening; IV, ripeness; V running ripe; VI spent. The spawning period was determined from the monthly distributions of the percentage frequency of gonad maturity stages and confirmed by the monthly variation of the gonadosomatic index (*GSI*). The *GSI* was calculated as follow:

$$GSI = \text{gonad weight / whole weight}$$

In order to determine the length at first maturity (the length at which 50% of the fish had become mature) only individuals collected during the spawning period were used. A logistic curve was fitted to the proportion of sexually mature individuals by length and the parameters were estimated using a least square method applied to a non-linear fit (King, 1995).

The timing of sex reversal was estimated by analysing the variation of the sex ratio (males/females) among the age classes (Kraljevic *et al.*, 1996).

Stomach content analysis

For the analysis of stomach contents 120 alimentary tracts were removed from individuals whose total length ranged from 156 to 310 mm. The samples were collected monthly from October 1997 to September 1998. The stomach was cut, its content was transferred to a petri dish laid on graph paper and the food was sorted into large zoological groups (food items) using a binocular dissecting microscope. Then, each food category was spread and squashed into a 1 mm uniform depth surface, in order to calculate its volume (Hellawell and Abel, 1971; Hyslop, 1980; Penczak, 1985). The number of individuals in each food category was recorded. When the amount of the fragmented Polychaeta and Crustacea could not be evaluated, their number was assumed to be equal to 1 (Arculeo *et al.*, 1993). The fraction of algae was excluded from the diet analysis because it was recorded as undigested food and was probably ingested by the fish together with other attached prey items (Badalamenti *et al.,* 1993).

Diet composition was analysed using the following indices (Hyslop, 1980):

percentage of frequency of occurrence (*F*): the percentage of non empty stomachs in which a food item was found;

percentage of numerical abundance (*N*): the percentage of total individuals of a food item in all food categories;

volumetric percentage (*V*): the volume of each prey item as a percentage of the total volume of the stomach contents.

The contribution of prey items in the fish diet was estimated using the index of relative importance (Pinkas *et al.*, 1971 in Hyslop, 1980):

$$IRI = (N + V) \times F$$

The *IRI* for each prey item was then expressed as ratio (%) of the total sum of *IRI*. The differences in the diet composition between fish age classes and season were examined using the Spearman rank correlation coefficient (Carasson *et al.*, 1992; Cortes, 1997; Fritz, 1974; Rosecchi, 1987) and the *t*-test was used to evaluate the statistical significance of the results. The Spearman rank correlation coefficient ranges from –1 (perfect negative correlation) to +1 (perfect positive correlation); the null hypothesis of no correlation is rejected at the 0.05 level of significance.

The heterogeneity (niche breadth) of food resources was calculated using the Shannon Wiener function (Krebs, 1985):

$$H = -\sum_{i=1}^{n} (p_i)(\ln p_i),$$

where p_i is the proportion of the *i* food category for the *n* food categories recorded. The proportion of food categories was estimated by the *IRI* percentage (Carasson *et al.,* 1992; Cortés *et al*., 1996). The Shannon-Wiener index value increases with the number of prey considered and with the evenness or equitability of prey distribution. To compare the differences in the niche breadth between fish size-classes and season, the index of equitability was used as described by Krebs (1985):

$$E = H / H_{max}$$

where: E = equitability; H = Shannon-Wiener index; and H_{max} = maximal evenness of species distribution (H_{max} = ln n). The index of equitability ranges between 0 and 1 and in practice values of E close to 0 indicate that the diet is represented by the high percentage of a few food items, whereas values of E close to 1 indicate that the prey items are evenly distributed. Differences in diet composition by age were analysed by grouping the samples into four age classes (less than 4 years, between 4 and 5 years, between 6 and 7 years and over 8 years) because of the lack of specimens in the lower and higher age classes.

All the statistical analyses were carried out using the STATISTICA package for Windows (StatSoft, 1984-1995).

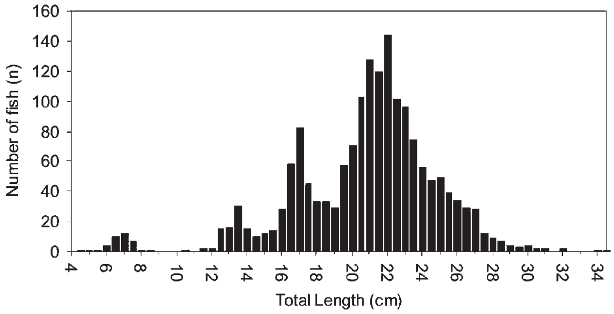

FIG. 1. – Total length frequency distribution for striped sea bream in the coastal waters of the Thracian Sea.

RESULTS

Length-weight relationship

The total length frequency distribution for all individuals is given in Fig. 1. For males, females, intersexuals (individuals with ovotestis) and all individuals, the range in size and weight and the parameters of the linear regression between the $\log_{10}$ of total length and the $\log_{10}$ of total weight are given in Table 1.

The determination coefficients (r^2) for all the regression analyses indicated a strong relationship between the variables ($P<0.001$). The slope (*b*-value) of the total length–total weight regression did not differ significantly between the males, females and intersexuals (ANCOVA: $F = 2.9745$; $F_{0.05(1),2,1562} = 3.00$; $P = 0.051$). Furthermore, the *b*-value for males, females and intersexuals was not significantly different (*t*-test) from the theoretical value of 3 (females: $t = 0.996$, $t_{0.05\ (2),\ 819} = 1.963$, $P = 0.486$; males $t = 0.454$, $t_{0.05\ (2),\ 475} = 1.965$, $P = 0.641$; intersexuals: $t = 1.837$, $t_{0.05\ (2),\ 268} = 1.968$, $P = 0.067$). Including the immature samples in the length-weight analysis, the *b*-value was found to differ significantly from 3 ($b = 3.104$; difference from 3; $t = 8.4119$, $t_{0.05\ (2),\ 1686} = 1.96$, $P<0.001$), conditioned by the positive allometric growth of the unsexed indi-

TABLE 1. – Parameters of length-weight relationship for males, females, intersexuals and unsexed separately, males, females and intersexuals (M+F+I) together, and all individuals together, sampled for *L. mormyrus* from the Thracian Sea.

		Total length (cm)		Total weight (g)						
	N	Min	Max	Min	Max	Log a	a	b	SE(b)	r^2
Males	477	10.4	28.8	19.3	313.9	-1.9331	0.01167	3.0156	0.0242	0.9701
Females	821	12.1	34.1	20.4	520.9	-1.8988	0.01262	2.9827	0.0176	0.9721
Intersexuals	270	14.7	30.7	45.4	364.4	-1.7746	0.01680	2.8794	0.0471	0.9329
M+F+I	1568	10.4	34.1	19.3	520.9	-1.8651	0.01364	2.9605	0.0131	0.9701
Unsexed	120	4.2	24.3	0.8	135.1	-2.2328	0.00585	3.2421	0.0167	0.9969
All	1688	4.2	34.1	0.8	520.9	-2.0664	0.00858	3.1084	0.0091	0.9855

TABLE 2. – Age frequency distribution by length classes and summary statistics of *L. mormyrus* from the Thracian Sea. (SD, standard deviation).

Length classes (mm)	Age (years)												
	0	1	2	3	4	5	6	7	8	9	10	11	Total
0-55	2												2
56-65	14												14
66-75	12												12
76-85	2												2
86-95													
96-105													
106-115		1											1
116-125		7											7
126-135		19	4										23
136-145		5	5										10
146-155			4	1									5
156-165			12	11									23
166-175			7	32	2								41
176-185				13	7								20
186-195				5	18	3							26
196-205				1	30	12	2						45
106-215					17	29	11						57
216-225					17	39	14	3					73
226-235					5	29	37	6					77
236-245						13	29	10	1				53
246-255						2	23	12	3				40
256-265							6	9	8				23
266-275							6	3	5	2			16
276-285							1	1	1	1			4
286-295										1			1
296-305										1			1
306-315											1		1
316-325													
326-335													
336-345												1	1
Age	0+	1	2	3	4	5	6	7	8	9	10	11	Total
N	30	32	32	63	96	127	129	44	18	5	1	1	578
%	5.19	5.54	5.54	10.9	16.6	22	22.3	7.61	3.11	0.87	0.17	0.17	
TL mean	65.4	130	154	172	203	221	237	248	262	282	310	341	
SD	6.69	6.67	13.2	8.36	13.6	12.6	15.3	13.4	9.97	12.9			
Mean size incr.	64.9	23.2	18.6	31.1	17.3	16.1	11.6	13.5					

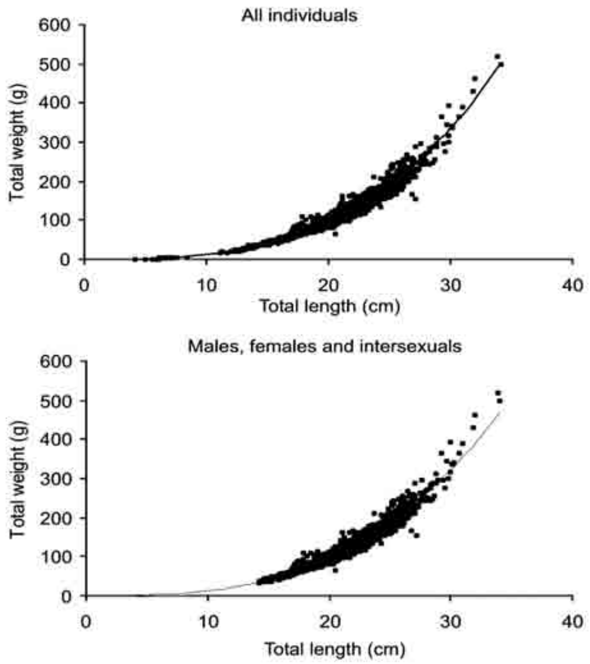

FIG. 2. – Length-weight relationship of *L. mormyrus* in the coastal area of the Thracian Sea: male, female and intersexuals together and for all individuals.

viduals (b = 3.242; t = 10.2957, $t_{0.05\,(2),\,118}$ = 1.98, P = <0.001). The length-weight relationship for males, females and intersexuals together and for the whole sample is represented in Fig. 3.

Age and growth

The size of specimens used for the age and growth analyses ranged from 51 to 341 mm (total length). Of the 721 otoliths that were extracted for the age estimation, only 578 were finally aged successfully. The rest were either broken or difficult to interpret. The age of the sample varied from 0+ to 11 years and was characterised by the high percentage of 4-, 5- and 6-year-old fish (Table 2). The mean size increments between successive age classes showed a rapid growth until the forth year, which slowed down considerably in the subsequent age-classes.

The monthly variation of the MIR (marginal increment ratio) confirmed the annual periodicity of the annulus formation, suggesting that the annulus was formed between January and May (Fig. 5).

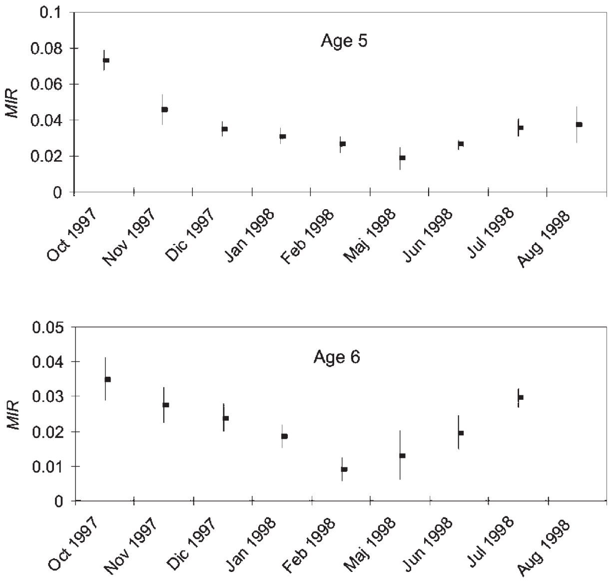

FIG. 3. – Mean monthly marginal increment ratio (MIR) for *L. mormyrus* 5 and 6 years old in the coastal area of the Thracian Sea. Vertical bars represent ± 1 standard error.

Since *L. mormyrus* is a protandric hermaphrodite, males, intersexuals and females were considered as the same individuals at different phases and not separated in the estimation of the growth parameters. The age-length key data obtained from otolith readings were adjusted assuming that 1 July is the birth date of *L. mormyrus* in the Thracian Sea (see reproduction section) and were used to fit the von Bertalanffy growth curve. The best fitting of the length-at-age data on the von Bertalanffy growth curve was highly significant, with a correlation coefficient of 0.95, and explained 90.79% of the variance (Fig. 7). The estimated von Bertalanffy

TABLE 3. – Back-calculated and predicted (VBGE) total lengths (mm) for *L. mormyrus* in the coastal area of the Thracian Sea; C.L., confidence limit.

Age (Yr)	N	Back-calculated	±95 % C.L.	Predicted
1	548	113.07	0.754409	105.97
2	489	143.27	0.866084	144.52
3	453	170.62	1.146347	175.76
4	407	194.10	1.192884	201.09
5	322	211.36	1.381294	221.62
6	196	228.68	1.859759	238.26
7	69	241.06	2.818721	251.75
8	25	256.52	4.235419	262.69
9	7	280.62	8.070361	271.55
10	2	305.48	19.39	278.74
11	1	330.75		284.56

growth parameters are: $L\infty = 309.482$ (S.E. = 9.71). $K = 0.21$ (S.E. = 0.0176) and $t_o = -0.996$ (S.E. = 0.116). The parameters used in the back-calculation formula were obtained from the linear regression between the fish total length and the otolith radius:

$$TL = -30.794 + 4.766 * (O) \quad r^2 = 0.932$$

The backcalculated length-at-age agreed with the predicted data, with the exception of 10 and 11 year classes (Table 3).

Mortality

For the construction of the length-converted catch curve, only the length-frequency data derived from trammel nets catches could be used as all the length classes were well represented. The total mortality rate estimated from the length-converted catch curve (Fig. 5) was $Z = 0.79$ year $^{-1}$. The natural mor-

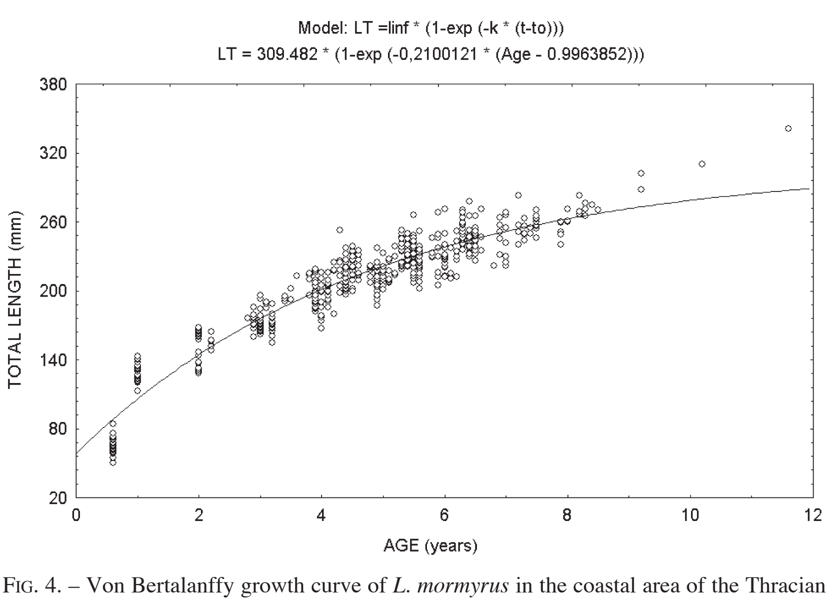

FIG. 4. – Von Bertalanffy growth curve of *L. mormyrus* in the coastal area of the Thracian Sea.

TABLE 4. – Number and percentage of females, males and intersexuals of *L. mormyrus* in the coastal area of the Thracian Sea.

Size classes	*Females* N	*Females* %	*Males* N	*Males* %	*Intersexuals* N	*Intersexuals* %	Male : female
<120	0	0.00	3	100.00	0	0.00	
121-140	19	35.19	35	64.81	0	0.00	1:0.54 *
141-160	26	44.07	32	54.24	1	1.69	1:0.81 *
161-180	76	43.43	97	55.43	2	1.14	1:0.78
181-200	90	51.14	61	34.66	25	14.20	1:1.48
201-220	242	51.71	149	31.84	77	16.45	1:1.62 *
221-240	176	57.33	63	20.52	68	22.15	1:2.79 *
241-260	110	67.90	29	17.90	23	14.20	1:3.79 *
261-280	59	79.73	5	6.76	10	13.51	1:11.80 *
281-300	14	82.35	1	5.88	2	11.76	1:14.00 *
301-320	5	100.00	0	0.00	0	0.00	
Total	817	54.47	475	31.67	208	13.87	1:1.72 *

* χ^2 test. Statistical difference at P<0.05 from the theoretical 1:1 sex ratio.

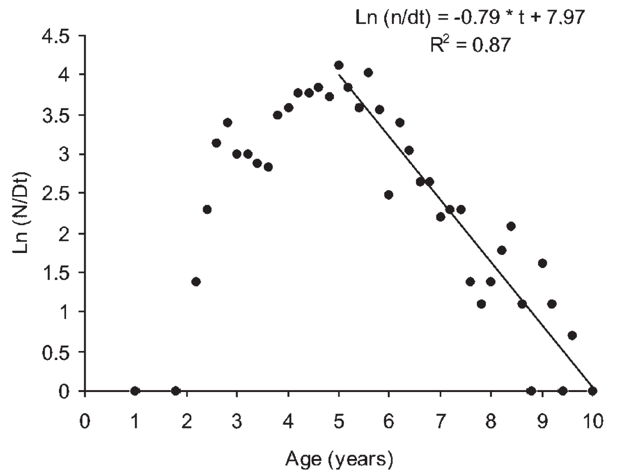

FIG. 5. – Length-converted catch curve for samples of *L. mormyrus* fished with trammel net.

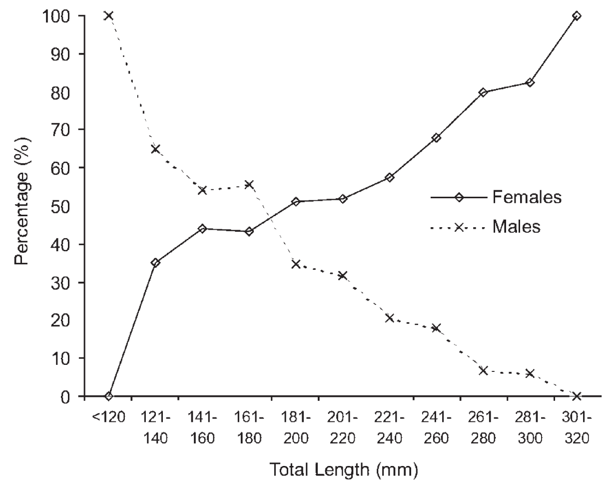

FIG. 6. – Sex reversal of *L. mormyrus* in the coastal area of the Thracian Sea.

tality rate was $M = 0.61$ year $^{-1}$ and the fishing mortality rate F = 0.18 year $^{-1}$.

Sex ratio, sex reversal and length at first maturity

Out of the number of striped sea bream that were sexed, 817 were found to be females, 475 males and 208 intersexuals. The overall ratio of males to females was 1:1.72 and the χ^2 test revealed a significant difference (P<0.05) from the theoretical 1:1 sex ratio. Sex ratios of males and females, grouped into 2 cm length classes showed a significant departure from the expected 1:1 (χ^2 test; P<0.05), except for the size classes from 161 to 200 mm total length. Males were predominant in the smaller and females in the larger length classes, confirming the protandric nature of the striped sea bream hermaphroditism. Sex inversion was observed initially at lengths between 181 and 200 mm (51% of the population) and mainly at lengths between 221 and 300 mm corresponding in age classes between 4 and 9 years. Samples larger than 300 mm were all females (Table 4 and Fig. 6).

The length corresponding to a proportion of 50% sexually mature individuals was (Fig. 7) 162.1 mm for males (2.5 years) and 190.4 mm for females (3.6 years).

Spawning period

The monthly variation of the maturity stages of *L. mormyrus* is shown in Figure 8. Running ripe individuals were collected from March to September and were dominant during June, July and August. Similar results were obtained from the analysis of the monthly variation of the gonadosomatic index (GSI). The GSI of males and females followed the same pattern and the highest values occurred in June, July and August (Fig. 9).

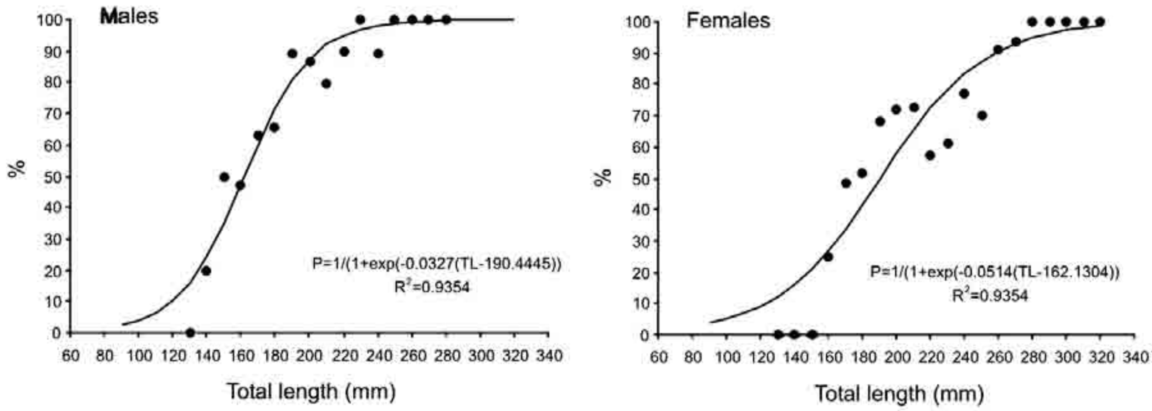

FIG. 7. – Sexual maturity curves for males (307) and females (326) of *L. mormyrus* in the Thracian Sea coastal area.

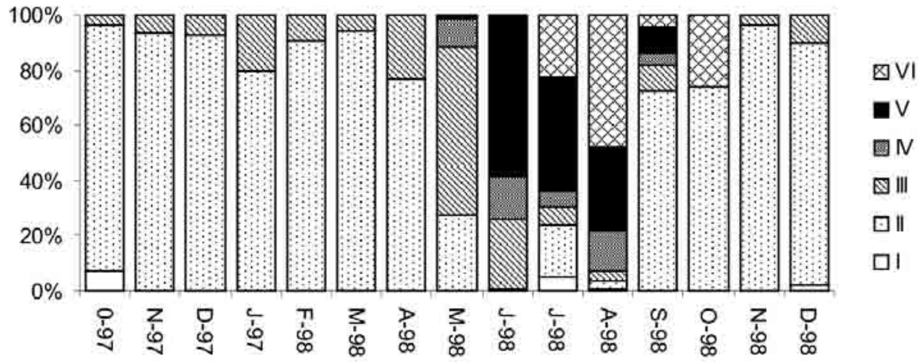

FIG. 8. – Monthly variation of the maturity stages *L. mormyrus* in the Thracian Sea.

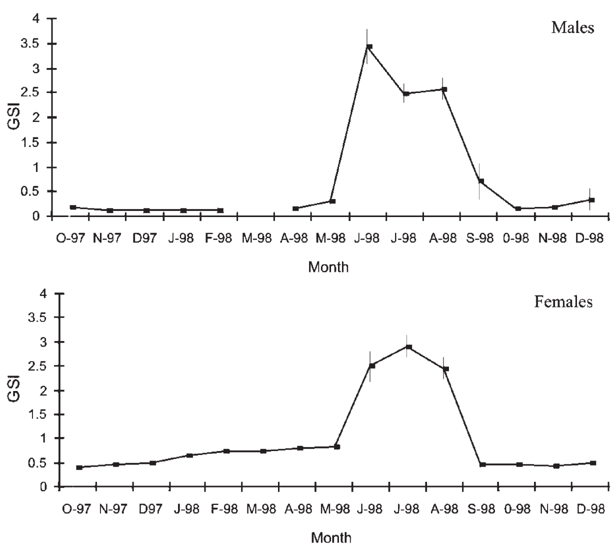

FIG. 9. – Monthly variation of the gonadosomatic index (GSI) for males and females of *L. mormyrus* in the Thracian Sea coastal area. Vertical bars represent ± 1 standard error.

Diet

One hundred and twenty *L. mormyrus* specimens were examined for diet analysis. The sample had a mean size of 233 mm TL, ranging from 156 mm to 310 mm, corresponding to the age-classes from 2 to 10 years old. Individuals with a total length up to 280 mm were aged using the values predicted by the VBGE, whereas the specimens larger than 280 mm were aged according to the back-calculated length-

TABLE 5. – Diet composition of *L. mormyrus* in the Thracian Sea coastal area expressed as frequency of occurrence (O), volume percentage (V), percentage by number (N) and the percentage of the index of relative importance (*IRI* %).

Prey items	O	V	N	IRI%
HYDROZOA	0.9	0.0	0.1	0.0
POLYCHAETA				
Errantia	40.0	7.4	13.6	7.9
Sedentaria	67.8	21.6	40.2	39.6
CRUSTACEA				
Copepoda	12.2	0.0	1.0	0.1
Mysidacea	0.9	0.0	0.0	0.0
Isopoda	8.7	0.6	0.6	0.1
Amphipoda	55.7	3.9	10.6	7.7
Euphausiacea	10.4	0.2	0.5	0.1
Decapoda				
Reptantia	7.8	3.4	1.6	0.3
Dec. not id.	24.4	3.9	2.2	1.3
Crus not id.	53.0	6.4	0.7	3.2
GASTEROPODA	47.0	2.7	7.3	4.5
BIVALVIA	74.8	29.4	19.1	32.8
ECHINODERMATA				
Echinoidea	20.0	1.9	2.2	0.7
PISCES parts	6.1	16.7	0.0	0.9
NOT.ID.	34.8	1.9	0.3	0.7

TABLE 6. – Correlation (Spearman rank correlation coefficient) of *L. mormyrus* diet composition between age classes and season.

Age classes	<4	4-5	6-7	> 8	Season	Winter	Spring	Summer	Autumn
<4 (14)	1				Winter (30)	1			
4-5 (53)	0.85	1			Spring (30)	0.62	1		
6-7 (36)	0.88	0.83	1		Summer (30)	0.73	0.91	1	
> 8 (17)	0.32*	0.62	0.58	1	Autumn (30)	0.32*	0.49*	0.58	1

* p-level of *t*-test >0.05. In parenthesis the number of stomachs analysed.

at-age data. Specimens aged between 4 and 7 years old represented 70% of the sample.

The diet composition is given in Table 5. Analysis based on the index of relative importance percentage (*IRI%*) showed that Polychaeta sedentaria (39.6%) and bivalvia (32.8%) make up 72% of the diet, followed by Polychaeta errantia (7.9%), amphipoda (7.7%) and gasteropoda (4.5%). The low value of the index of equitability ($E = 0.57$) confirmed that a few prey items dominated the diet.

Ontogenetic and seasonal variation of diet

According to the Spearman rank correlation coefficient, only the diet composition of the age-classes of less than 4 and more than 8 years was not significantly correlated (r-Spearman = 0.32, p = 0.28). Differences were found either in the consumption of the preys dominating the diet (sedentaria for specimens less than 4 years old and bivalvia, sedentaria and echinoidea for specimens more than 8 years old) or in the consumption of secondary preys. The rest of the age-classes were well correlated (Table 6). The coefficient of equitability increased among the size-classes ranging from 0.52 (age-classes less than 4 years) to 0.77 (age-classes more than 8 years), showing that the relative percentage of the food items becomes more evenly distributed with increasing size (Fig. 10). The trend of the coefficient of equitability was mainly explained by the variation in the relative percentage of the preys dominating the diet among the age-classes. In the age-classes of less than 4 years the diet was dominated only by sedentaria (68%); between 4 and 5 years by sedentaria (45.2%) and bivalvia (33.8%); between 6 and 7 years by bivalvia (34%), sedentaria (26.6%) and errantia (21.4%); and between 8 and 10 years by bivalvia (29.6%), sedentaria (16.9%), echinoidea (13%) and a relevant percentage (14.8% in total) of gasteropoda (8.1%) and remains of fish (6.7%).

Seasonally, the coefficient of equitability (Fig. 11) was characterised by a high value (E = 0.75) in winter followed by a decline in spring (E = 0.56) and summer (E = 0.41) and an increase in autumn (E = 0.58). The trend of the equitability coefficient was reflected in the percentage composition of the preys dominating the diet in the different seasons. In winter the diet was dominated (76% in total) by decapoda (24%), amphipoda (21.4%) and sedentaria (16.6%), followed by a considerable percentage of bivalvia (13%). In spring the diet was dominated

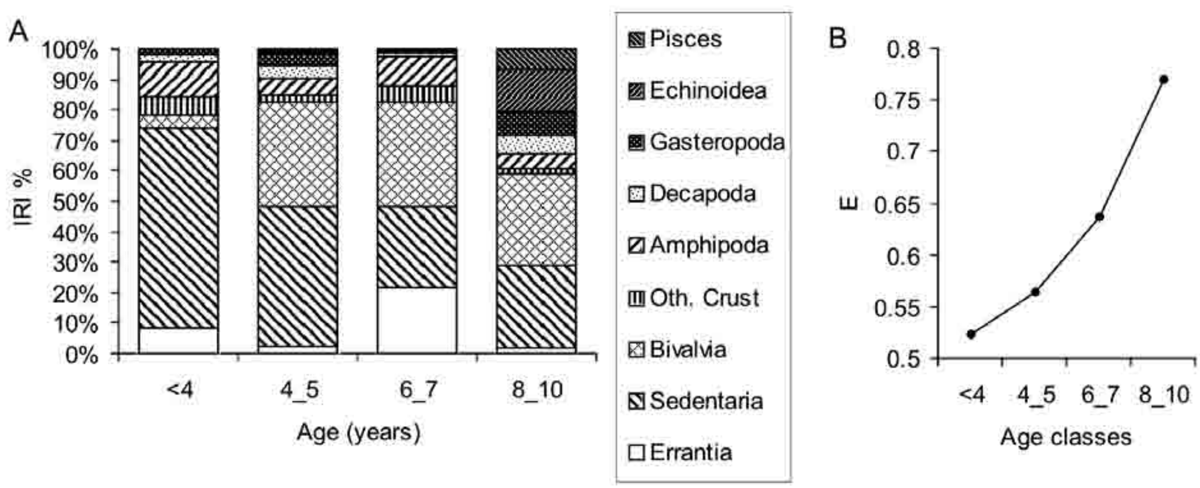

FIG. 10. – A) Ontogenetic variation of *L. mormyrus* diet composition based on the index of relative importance percentage (IRI%). B) Onto genetic variation of the index of equitability (E).

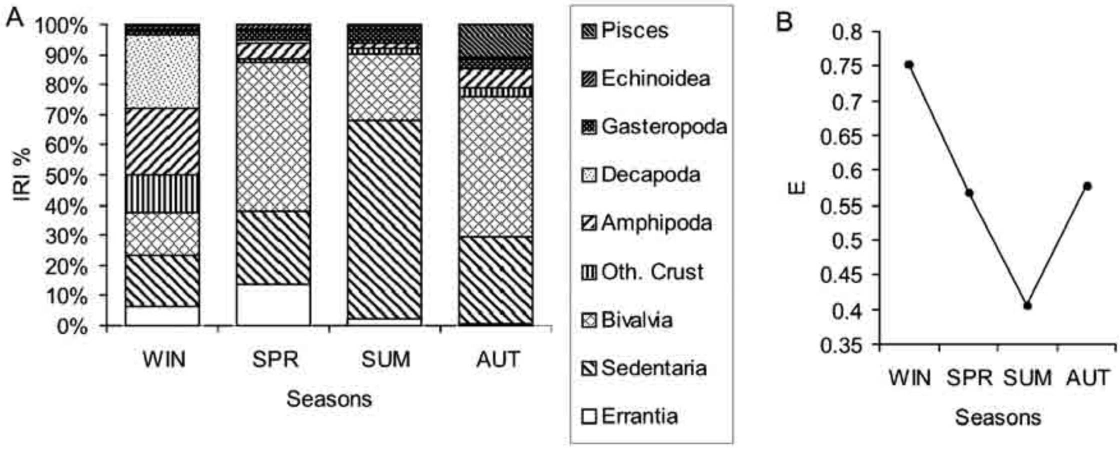

FIG. 11. – A) Seasonal variation of *L. mormyrus* diet composition based on the index of relative importance percentage (IRI%). B) Seasonal variation of the index of equitability (E).

(86.2% in total) by bivalvia (48.5%), sedentaria (24.1%) and errantia (13.6%). In summer the diet was dominated (87% in total) by sedentaria (65.5%) and bivalvia (22.1%). Differences in the diet composition (Spearman test) were found between autumn and winter in the consumption of the preys dominating the diet (bivalvia and sedentaria in autumn and decapoda and amphipoda in winter) and between spring and autumn in the consumption of the secondary preys.

DISCUSSION

Analysis of the length-weight relationship of the immature *L. mormyrus* (42 to 243 mm in total length) from the coastal water of the Thracian Sea showed a positive allometric growth ind,icating that in the juvenile period the species becomes heavier with increasing length. This is in agreement with the results of Koutrakis and Tsikliras (2003), who published a length-weight relationship of *L. mormyrus* in the northern Aegean estuarine systems using 73 samples ranging in size (total length) between 21 and 143 mm. On the other hand, the estimated parameters of the length-weight relationship for males, females and intersexuals show an isometric growth and no differences in the relative growth rate between sexes. These results agree with those of Kraljevic *et al*. (1995, 1996) from the northern Adriatic Sea and Suau (1970) from the Castellón coast (eastern Spain) for fish ranging between 100 and 200 mm in TL. However, they contrast with those of Kraljevic *et al*. (1995) in the middle Adriatic Sea (negative allometric growth), Suau (1970) for fish ranging between 210 and 290 mm TL (positive allometric growth), Lorenzo *et al*. (2002) from the Canary Islands (negative allometric growth and difference between sexes) and Gonçalves *et al*. (1997) from the southwest coast of Portugal (negative allometric growth). The length-weight relationship may be influenced by sex, maturity, geographical location and environmental condition (Balon, 1984; Bagenal and Tesch, 1978). The differences between the growth patterns of immature and mature individuals of *L. mormyrus* in the present study may be explained by the changes in the environmental conditions between juvenile and adult habitats.

The sagittae of *L. mormyrus* in the area considered show distinct opaque and hyaline zones and allowed us to age the samples assuming that the hyaline and the opaque succession (annulus) is formed annually (William and Bedford, 1974). The annual periodicity of annuli formation is confirmed by the marginal increment analysis, suggesting that the hyaline zone is completed between January and May and that the use of the sagittal otolith is appropriate for ageing the species. The values of the mean total length-at-age are close to those reported until the age classes 4 and 4+ (Table 7) by Suau (1970), who used the scale reading for ageing the striped sea bream from the Castellón coast (eastern Spain). For age-classes of more than 4 years the values differ considerably. The differences are even more remarkable when one compares the results from the present study with those reported by Kraljevich *et al*. (1995, 1996) for *L. mormyrus* from the northern Adriatic Sea and by Lorenzo *et al*. (2002) from the central-east Atlantic (Canary Islands). The population of *L. mormyrus* in the Thracian Sea reaches the same age as other populations of the Mediterranean Sea (Kraljevich *et al.,* 1996) and of the central-east Atlantic

TABLE 7. – Age-at-length of *L. mormyrus* according to various authors.

Age classes	Suau (1970) [1]	Kraljevic *et al.* (1995) [2]	Mean lengths (mm) at age Kraljevic *et al.* (1996) [3]	Lorenzo *et al.* (2002) [4]	Present study
0+				124	65
1	125.7 (1+)			161	130
2	164.5 (2+)			209	154
3	182	217	208	243	172
4	209.8	268	257	279	203
5	253.9 (5+)	284	281	303	221
6	282.6 (6+)	303	300	325	237
7		316	313	344	248
8			327	357	262
9			339	365	282
10			351	371	310
11					341
12			376		

eastern Spain; 2) middle Adriatic; 3) northern Adriatic; 4) Canary islands.

TABLE 8. – Growth parameters of *L. mormyrus* according to various authors.

	Suau, 1970[1]	Kraljevic *et al.*,1995[2]	Kraljevic *et al.* (1995)[3]	Kraljevic *et al.* (1996)[4]	Lorenzo *et al.* (2002)[5]	Present study
K	0.275	0.297	0.262	0.196	0.188	0.21
$L\infty$ (mm)	332.7	362	373	400.5	429	309.5
t_o (yrs)	0.057	-0.08	-0.39	-0.945	- 1.37	-0,996
Observed age (yrs)	1+ – 6+	3 – 8	2+ – 7+	3 – 12	0+ – 10	0+ – 11

1) eastern Spain; 2) middle Adriatic; 3) northern Adriatic; 4) northern Adriatic; 5) Canary islands.

(Lorenzo *et al*., 2002) but obtains a smaller size-at-age. The asymptotic length ($L\infty$) is found to be smaller than those estimated by Suau (1970), Kraljevich *et al*. (1995-1996) and Lorenzo *et al*. (2002). The growth rate (k) of the species in the Thracian Sea is relatively slow, which is in agreement with the results of the other authors (Table 8). The estimated value of $L\infty$ (309.4 mm) is considerably lower than the maximal total length observed in the sample, which may be due to the high presence of juveniles. Moreover, t_o is found to be negative and considerably different from 0, indicating that the early stages are not well described by the VBGE (Fig. 3). It is concluded that the VBGE has a good prediction only for the age-classes between 2 and 9 years and does not accurately describe the growth during the early and later stage of the fish life. Gonçalves *et al*. (2003) found similar results in ageing *Diplodus vulgaris* from the south coast of Portugal and concluded that the underestimation of $L\infty$ may be due to the special characteristics of growth of sparid fish; growth rate tends to be very fast in the juvenile stages and slows down considerably in the adult stages. Gordoa and Molí (1997) suggested that the differences in growth between juvenile and adult stages of the sparids *Diplodus sargus* and *D. vulgaris* from the northwestern Mediterranean Sea may be attributed to the differences in the environmental conditions between the different stages of their development. In the coastal area of the Thracian Sea the juveniles of *L. mormyrus* inhabit the shoreline (personal observation) and the estuaries (Koutrakis and Tsikliras, 2003). This indicates that, after the pelagic larval and post-larval stage (Suau, 1970), juveniles migrate close to the coast, often enter the shallow waters of the estuarine systems, and then join the adult schools in deeper waters before reaching sexual maturity. Changes in the environmental conditions (mainly temperature, salinity and food availability) in the different habitats may be responsible for the differences recorded between juveniles and adult growth pattern (Wotton, 1990).

The total mortality rate (Z = 0.79 year^{-1}) of *L. mormyrus* caught with trammel nets gave a relatively high natural mortality rate (M = 0.61 years^{-1}) compared with that of Kraljevich *et al*. (1996) from the northern Adriatic Sea (M = 0.42) and Lorenzo *et al*. (2002) from the central-east Atlantic (M between 0.3 and 0.45 years^{-1}). The low fishing mortality rate (F = 0.18 years^{-1}) suggests that the trammel net fishery may be sustainable. These results should be taken with caution because they do not consider the impact on the *L. mormyrus* population of the other fishery gears such as gill nets, fyke nets, bottom long lines and beach seines. Further study on size selectivity and mortality rates for all gears used as well as yield per recruit analysis is required in order to determine the real exploitation of the *L. mormyrus* population in the coastal water of the Thracian Sea.

The presence of intersexuals and the predominance of males at smaller sizes and females at larger sizes indicate that *L. mormyrus* in the Thracian Sea coastal water is a protandric hermaphrodite species. These results agree with those of Bessau (1990), Kraljevich *et al*. (1995, 1996) and Lorenzo *et al*. (2002). Furthermore, the present work suggests that the sex inversion takes place mainly between 210 and 300 mm (4-9 age classes), in agreement with the results of Kraljevich *et al*. (1995, 1996). The protandric hermaphroditism of the species may explain (Lorenzo *et al*., 2002; Pajuelo and Lorenzo, 1996) the differences observed in the age at sexual maturity between males and females (2.5 years for males and 3.6 years for females). These results agree with those of Lorenzo *et al*. (2002) for *L. mormyrus* off the Canary Islands.

The spawning period of *L. mormyrus* from the Thracian Sea occurs mainly between May and September, with the maximum gamete emission taking place in June, July and August. These results are in good accordance with those of Suau (1970) for the same species on the Spanish Mediterranean coast, confirming that *L. mormyrus* is a summer spawner within the Mediterranean. The maximal gonadal activity of *L. mormyrus* reported by Lorenzo *et al*. (2002) in the central-east Atlantic is shifted one month later (August-September). If the temperature is the most important environmental factor affecting the gonadal maturation and time of gamete emission of summer spawners (Lorenzo *et al*., 2002; Pajuelo and Lorenzo, 1996; Wotton, 1990), then the differences observed in the reproductive season between the Mediterranean Sea and the central-east Atlantic may be explained by the differences in the seasonal variation of the temperature.

The diet composition suggests that the striped sea bream from the Thracian Sea is a carnivore species feeding on benthic invertebrates, mainly Polychaeta and bivalve molluscs. The results agree with those of Badalamenti *et al*. (1992) for *L. mormyrus* on the northwest coast of Sicily. Suau (1970) and Froglia (1977) used the frequency of occurrence to assess the diet composition of *L. mormyrus*, finding results that are in good agreement with those reported in the present study. For instance, Froglia (1977) found that there is a remarkable occurrence of amphipods in the diet of specimens older than 0+ years. The present work found a considerable contribution of amphipods to the diet composition, with values of 50 to 66% in specimens between 2 and 8 years old. Nevertheless, as amphipods were poor in volume percentage, their index of relative importance (IRI) was less than 10%. It is concluded that the frequency of occurrence alone limits the accurate determination of the species diet composition.

The ontogenetic variation of the diet composition showed that, while growing, *L. mormyrus* becomes a more generalist feeder, which is in accordance with the results of Froglia (1977) from the Central Adriatic Sea. The relative proportion of preys that dominate the diet of the species changes with increasing age; the percentage of Polychaeta sedentaria decreases while that of mollusca bivalvia, Polychaeta errantia and echinoidea increases. In agreement with the results of Froglia (1977) and Suau (1970), remains of echinoderms and bivalves are common in the diet of adult species and, as Froglia (1977) pointed out, remains of fish can be found only in the diet of larger specimens. It is suggested that the ontogenetic variation in the food resources and in the niche breadth may be related to the ability of larger specimens to grind hard parts of animals such as shells of bivalvia and skeletal plates of echinoidea and to capture larger animals. The high percentage of Polychaeta sedentaria found in the diet of specimens less than 4 years old may be related to the particular feeding behaviour of younger fish, suggesting that these preys are the most profitable for this stage of life. The common presence in the diet of our sample of sand grains and pieces of undigested algae associated with benthic organisms suggests that *L. mormyrus* is a bottom feeder, actively seeking the preys located in the sediments. These results agree with those of Suau (1970) from the eastern Spanish coast, Froglia (1977) from the western Adriatic coast and Badalamenti *et al*. (1992) from the northwest coast of Sicily.

Seasonally, the diet of *L. mormyrus* in this study area is characterised by a considerable variation in the feeding niche, showing that the species becomes a more selective feeder in summer and a more generalist feeder in winter. These changes may be correlated to the seasonal variations in food availability, and could be better understood through a careful study of the abundance of the prey organism in this study area. Furthermore, the predominance of Polychaeta sedentaria found in both the diet of the younger specimens and the diet of samples caught in summer seems to be related to a particular feeding behaviour. It seems to become more beneficial for the younger fish and for the species in summer to feed on Polychaeta sedentaria because they are immobile and easily available in the sediment. These observations suggest that Polychaeta sedentaria are the most profitable preys, in terms of energy content and energy cost of acquisition, for the supply of energy needed for important physiological events such as the rapid growth of young specimens and the sexual maturation occurring in summer. Further studies must be carried out to confirm these hypotheses and to complete our knowledge on the feeding behaviour of *L. mormyrus*.

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