Age, growth, reproduction and mortality of the striped seabream, *Lithognathus mormyrus* (Pisces, Sparidae), off the Canary Islands (Central-east Atlantic)

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Summary

Striped seabream, *Lithognathus mormyrus* L. (n = 731) caught off the Canary Islands from January 1999 to June 2000 were studied. Fish ranged in size from 113 to 372 mm total length, weighing from 21.1 to 748.2 g total weight. Weight increased allometrically with size (b = 2.9071). Fish age was 0–10-years-old. Growth was relatively slow (k = 0.88 years^{-1}), with females growing at a slightly faster rate than males. The species displayed protandric hermaphroditism. Male : female ratio was unbalanced in favour of males (1 : 0.85). Males predominated in smaller sizes, females in larger sizes, and intersexual individuals were in intermediate sizes. The reproductive season extended from June to December, with a peak in spawning activity in August–September. Males reached maturity at 207 mm (2 years) and females at 246 mm (3 years). The real value of instantaneous rate of natural mortality was between 0.30 and 0.45 years^{-1}.

Introduction

In the Canary Islands, members of the family Sparidae are very common and are represented by 24 species (Brito 1991; Franquet and Brito 1995). In this region, sparids are subject to commercial exploitation and constitute the main target family of the small-scale demersal fishery (Pajuelo 1997). One of sparids found in the Canarian archipelago is the striped seabream *Lithognathus mormyrus* (Linnaeus 1758), the only species of the genus *Lithognathus* recognized to date in the area.

The striped seabream is a demersal fish group inhabiting various types of sea bottoms, especially rocky, sand and seagrass beds, at depths ranging from 0 to 150 m (Bauchot and Hureau 1986, 1990). This species is distributed in the Eastern Atlantic and the Western Indian Ocean. In the Eastern Atlantic, it occurs from the Bay of Biscay to the Cape of Good Hope, and around the Canaries and Cape Verde. It is also present in the Mediterranean, Black, Azov and Red seas. In the Western Indian Ocean, it occurs from Southern Mozambique to the Cape of Good Hope (Smith and Smith 1986; Bauchot and Hureau 1986, 1990; Harmelin-Vivien et al. 1995).

In the Canary Islands, the striped seabream is caught mainly with traps at depths ranging between 10 and 100 m. This species is captured all year round with significant seasonal differences in the landings. No bag limits are currently imposed on its fishery.

The striped seabream has never been the subject of investigation in the Canary Islands, and information published on its presence in the Atlantic Ocean is very scarce. Only aspects on its distribution (Magnússon and Magnússon 1987; Ofori-adu 1988) and its length–weight relationship (Dorel 1985; Magnússon and Magnússon 1987; Gonçalves et al. 1997) have been described. This study investigates aspects of the biology of the striped seabream off the Canary Islands, including age, growth, reproduction and mortality, which may be used to develop a management strategy for the species.

Materials and methods

The study consisted of a total of 731 individuals of striped seabream collected from the commercial catches of the artisanal fleet between January 1999 and June 2000. Fish were caught with traps deployed on the bottom at depths of 4–90 m off Gran Canaria, Canary Islands (Central-east Atlantic).

For each individual, the total length (TL, mm) and the total weight (TW, 0.1 g) were measured. The sex and the stage of maturity were recorded by macroscopic examination of the gonads, and the weight of the gonads (GW, 0.01 g) was recorded. The stages of maturation were classified as follows: I, immature; II, resting; III, ripe; IV, ripe and running; and V, spent. Sagittal otoliths were removed, cleaned, and stored dry in envelopes with a code number.

Total length and total weight ranges of fish were determined. The total length–total weight relationship was established by linear regression (Ricker 1973).

Age was determined by reading the otoliths. Otoliths were read whole, under a compound microscope at 15 × magnification using reflected light while immersed in a solution of glycerine and alcohol. Age estimates were obtained by counting the number of opaque bands from the nucleus to the margin. As a rule, each otolith was read three times by the senior author, and readings for a given otolith were accepted only when two readings agreed. The average percentage error (APE), developed by Beamish and Fournier (1981), was used to evaluate the precision of age determinations. The percentage of otoliths with opaque margin was calculated for each month to determine the periodicity and timing of ring formation. This method allowed the annual formation of the rings to be determined; once the rings were confirmed to be annual, the age of each fish was determined and assigned to a year class, taking into account the date of capture, the annuli formation period, and the reproductive biology of the species in the area (Morales-Nin 1987). Thus, 1 September was considered as the birth date. The von Bertalanffy growth curve (Beverton and Holt 1957) was fitted to data of the resulting age–length key by means of Marquardt's algorithm for non-linear least squares parameter estimation (Saila et al. 1988). The growth

performance index (Φ) was used to compare the values of the growth parameters given in the present paper with those reported by other authors for the same species (Pauly and Munro 1984).

The sexual pattern was established, taking into account the sex determinations. The overall sex ratio (males : females) and the sex ratios by size intervals (10 mm) were determined considering the number of males and females.

The reproductive period was established by analysing the temporal evolution in the percentage frequency of the maturity stages and the values of the gonadosomatic index (Anderson and Gutreuter 1983).

The length at first maturity (length at which 50% of the fish had become mature) was determined from the relationship between the length class and the percentage of mature fish in each size class. A logistic function was fitted to data by means of Marquardt's algorithm for non-linear least squares parameter estimation (Saila et al. 1988).

The instantaneous rate of natural mortality (M) was estimated using different classical methods (Beverton and Holt 1959; Tanaka 1960; Taylor 1960; Rikhter and Efanov 1976; Pauly 1980; Hoenig 1983). To delimit a range of values of this rate that includes its real value, the longevity for each value of M was estimated using the method of Alagaraja (1984).

Results

Fish ranged in size from 113 to 372 mm total length, weighing from 21.1 to 748.2 g total weight. The length of males ranged between 184 and 350 mm, and their weight between 105.3 and 585.4 g. The length of females ranged between 199 and 372 mm, and their weight between 123.8 and 748.2 g. Intersexual individuals ranged from 215 to 323 mm in length, and from 145.5 to 559.2 g in weight. Immature fish were found at sizes of 113–230 mm, and weights of 21.1–172.1 g.

The length–weight regressions indicated a negative allometric nature of growth in males, females and all individuals (Table 1 and Fig. 1). Significant difference in the allometric coefficient of the regression was found between males and females (t-test, $t = 9.07 > t_{0.05,646} = 1.65$), with females being slightly heavier than males for a given length.

Of the total otoliths examined, 687 (93.4%) yielded useful age estimates and 44 (6.6%) were discarded as they were either broken or difficult to interpret. The concentric pattern of opaque and translucent zones was readily distinguishable in the otoliths and was easily interpreted. The APE value was only 2.5%. One opaque zone was deposited throughout the year with differing monthly frequency; the highest percentages of otoliths with opaque rings at the margin were observed between May and September (Fig. 2).

Fish aged 0–10 years old were observed in the samples (Table 2). Significant differences in the growth parameters
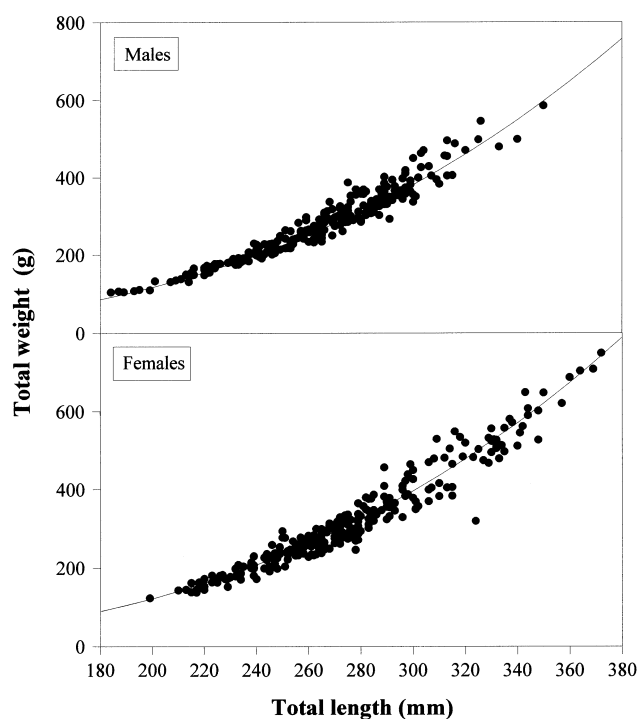
Table 1
Parameters of the length–weight relationship for males, females and all individuals of *Lithognathus mormyrus* off the Canary Islands (January 1999–June 2000), and the possibility of isometry tested by Student's t-test

	a	b	SE(b)	n	r[2]	t-test
Males	0.0000225	2.8656	0.0483	351	0.949	2.78[a]
Females	0.0000267	2.9124	0.0314	297	0.953	2.79[a]
All fish	0.0000275	2.9071	0.0289	731	0.968	3.21[a]

[a]($t > t_{0.05,n > 100} = 1.65$).

Fig. 1. Length–weight relationship for males (n = 351) and females (n = 297) of *Lithognathus mormyrus* off the Canary Islands (January 1999–June 2000)
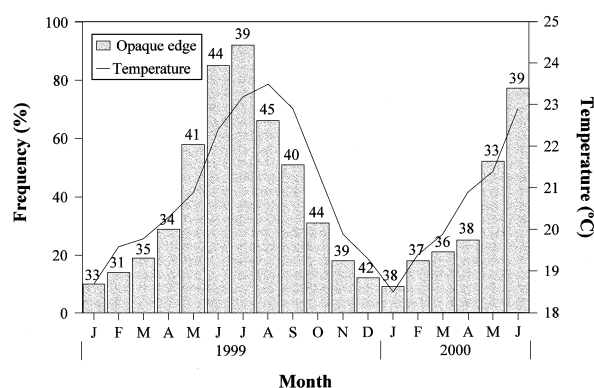

Fig. 2. Monthly percentage of otoliths with opaque edge (n = 687) for all individuals of *Lithognathus mormyrus* off the Canary Islands, number of otoliths examined by month, and monthly evolution of the sea temperature (January 1999–June 2000)

were found between sexes (Hotelling's T^2-test, $T^2 = 27.18 > T^2_{0.05,3,670} = 7.85$), with females growing at a slightly faster rate than males (Table 3). The value of the growth performance index obtained for all individuals was $\Phi = 4.54$. Table 4 gives the values of the growth performance index estimated for the striped seabream in different geographical areas where its growth has been studied.

The gonads were elongated and were suspended by a dorsal mesentery in the posterior region of the visceral cavity. In general, both gonadal lobes were equally well developed.

Of the total individuals examined, 351 (48.0%) were males, 297 (40.6%) females, and 59 (8.1%) intersexuals. The sex of the remaining 24 (3.3%) fish could not be identified macroscopically because they were immature with very thin and translucent gonads. The overall ratio of males to females was 1 : 0.85; thus both sexes were not equally represented and the

Table 2
Age–length key for all individuals of *Lithognathus mormyrus* off the Canary Islands (January 1999–June 2000)

Size (mm)	Age group (years)										
	0	I	II	III	IV	V	VI	VII	VIII	IX	X
110	1										
120	2	1									
130	1	1									
140		2									
150		3									
160		5									
170		3	2								
180		1	5								
190			11								
200			24	2							
210			31	7							
220			17	18	2						
230			9	27	6						
240			3	38	12						
250				46	21	1					
260				23	41	4					
270				14	57	9					
280				5	45	14					
290				1	26	19	1				
300					8	26	4				
310					1	17	8	1			
320						11	12	2			
330						3	7	3			
340							2	4	2		
350								2	4	2	
360									1	2	1
370										1	2
n	4	16	102	181	219	104	34	12	7	5	3
x	124	161	209	243	279	303	325	344	357	365	371
SD	18	29	22	19	18	18	16	12	5	3	2

n, number of fish × the mean value; SD, standard deviation.

Table 3
Parameters of the von Bertalanffy growth curve for males females and all individuals of *Lithognathus mormyrus* off the Canary Islands (January 1999–June 2000)

	L_∞ (cm)	k (/years^{-1})	t_0 (years)	n	r^2
Males	407	0.227	−0.87	331	0.977
Females	448	0.182	−1.32	289	0.981
All fish	429	0.188	−1.37	687	0.980

Table 4
Values of the growth performance index (Φ) for *Lithognathus mormyrus* in different geographical areas

Area	Φ	Authors
Western Mediterranean	4.49	Suau (1970)
Eastern Adriatic	4.56	Kraljević et al. (1995)
Northern Adriatic	4.50	Kraljević et al. (1996)
Canary Islands	4.54	Present paper

hypothesis that the sex ratio was 1 : 1 must be rejected ($\chi^2 = 4.50 > \chi_{t\,1,0.05}^2 = 3.84$). Males predominated in smaller size intervals and females in larger sizes; intersexual individuals were intermediate in size between males and females (Fig. 3). Sex ratios by size intervals had significant departures from the 1 : 1 ratio ($\chi^2 > \chi_{t\,1,0.05}^2 = 3.84$) for most size categories, except for the mid-size groups (240–280 mm).

Males and females with ripe gonads (stage III) were recorded between June and September, being dominant in July; ripe and running males and females (stage IV) appeared in July and became dominant in August and September; spent males and females (stage V) were recorded from October to November (Fig. 4). Although the gonadosomatic index of females was usually higher than that of males, the same pattern was recorded for both sexes; the highest values occurred between June and November, with a maximum in August–September (Fig. 5).

The smallest mature males and females were 184 and 203 mm, respectively. Individuals smaller than 190 mm showed little evidence of sexual activity. Of males and females 50% matured at 207 and 246 mm, respectively (Fig. 6). Significant difference in length at first maturity was found between males and females (*t*-test, $t = 5.7 > t_{0.05,282} = 1.65$).

The values of the instantaneous rate of natural mortality ranged between 0.30 and 0.53/years^{-1}, and the longevity between 8.6 and 15.3/years^{-1} (Table 5).

Discussion

A negative allometric growth between size and weight was observed for males, females and all individuals of striped seabream off the Canarian archipelago. This agrees with the results reported in all studies which deal with the length–weight relationship of the species in the Atlantic Ocean (Dorel 1985; Magnússon and Magnússon 1987; Gonçalves et al. 1997). The difference between males and females in the length–weight relationship is due to the different size distributions of the two sexes, as a consequence of the protandric hermaphroditism. Kraljević et al. (1996) also found differences in the
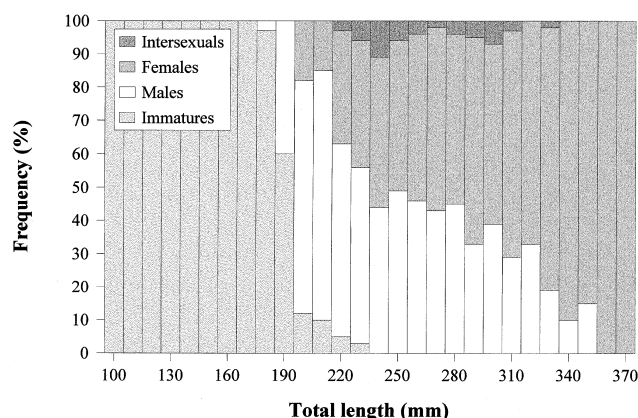
Fig. 3. Frequency of immatures (n = 24), males (n = 351), females (n = 297) and intersexuals (n = 59) of *Lithognathus mormyrus* off the Canary Islands by size classes (January 1999–June 2000)
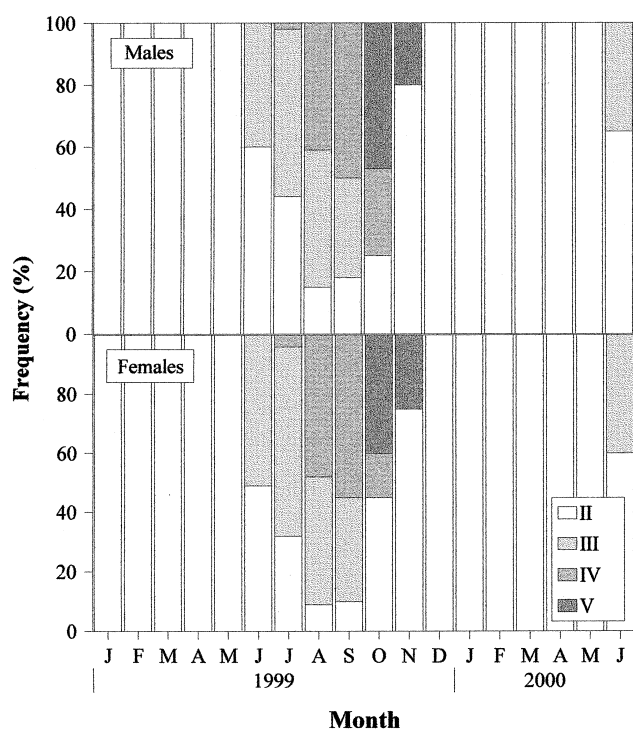

Fig. 4. Monthly evolution of the maturity stages for males (n = 351) and females (n = 297) of *Lithognathus mormyrus* off the Canary Islands (January 1999–June 2000)

Fig. 5. Monthly evolution of the gonadosomatic index (GSI) for males (n = 351) and females (n = 297) of *Lithognathus mormyrus* off the Canary Islands (January 1999–June 2000). Vertical lines indicate standard deviation

Fig. 6. Sexual maturity curves for males (n = 151) and females (n = 133) of *Lithognathus mormyrus* off the Canary Islands (January 1999–June 2000). The lines indicate the 50%-values for maturity

length–weight relationship of males and females for this species in the Northern Adriatic.

The alternate pattern of opaque with translucent zones is easily distinguishable on the otoliths of the striped seabream off the Canary Islands, allowing relative ease of age determination. These zones are deposited owing to alternating periods of rapid and slow growth (Williams and Bedford 1974). The opaque zone is formed when the water temperature is higher; the translucent is formed when the temperature is lower (Fig. 2).

The oldest fish found in this study were 10 years of age, although these individuals and those 8 and 9 years of age are poorly represented in the landings. Suau (1970), on the Spanish Mediterranean coast, found that individuals of striped seabream may attain an age of 7 years. Kraljević et al. (1995,
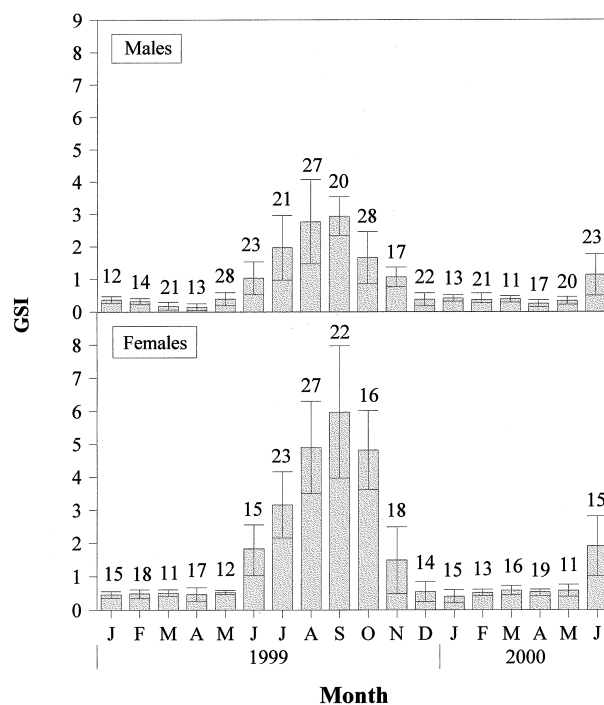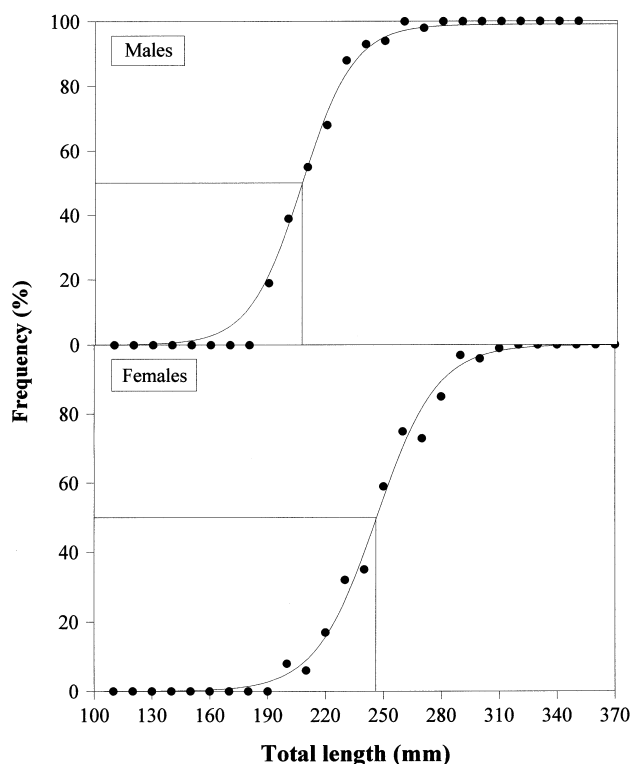
1996), in the Eastern Adriatic and in the Northern Adriatic, found that this species can attain an age of 8 and 12 years, respectively.

Table 5
Values of instantaneous rate of natural mortality (M) and longevity for all individuals of *Lithognathus mormyrus* off the Canary Islands estimated by different methods (January 1999–June 2000)

Method	M (/year)	Longevity (years)
Beverton and Holt (1959)	0.50	9.2
Rikhter and Efanov (1976)	0.53	8.6
Tanaka (1960)	0.30	15.3
Taylor (1960)	0.32	14.6
Hoenig (1983)	0.45	10.2
Pauly (1980)	0.44	10.5

Growth of the striped seabream off the Canary Islands is relatively slow, with females growing at a slightly faster rate than males and showing the typical pattern of the protandric sparids (Buxton 1993). Alekseev (1983) and Shapiro (1984) indicated that the mean length of sex-reversed individuals is slightly longer than the average length of the males at the same age. Therefore, the difference in length between males and females of the same age cannot be considered as evidence of intersexual difference in growth rates because males and females are the same individuals at different phases of sexual succession and, possibly, the largest males in an age group are the first to change sex (Shapiro 1984). The growth of the striped seabream off the Canarian archipelago is similar to that reported for the same species in other regions (Table 4).

Among the numerous families of teleosts, sparids exhibit some of the most diversified modes of sexuality. In this family, both forms of sequential hermaphroditism (protogyny and protandry) have been found, as well as rudimentary hermaphroditism leading to secondary gonochorism. This variability is probably linked to the peculiar configuration of the gonad, an ovotestis, that is characteristic of all species of the family (Buxton and Garratt 1990).

The presence of individuals with ovotestes and the predominance of males at smaller sizes and females at larger sizes suggest that the striped seabream off the Canary Islands displays protandric hermaphroditism. Related to this, Shapiro (1984) and Smale (1988) pointed out that sex-changing fishes often have bimodal length-frequency distributions and indicated that the sex ratios of protandric sparids may be skewed towards the males. In the case of protandric species, small individuals are usually males and large specimens are usually females. D'Ancona (1949), Reinboth (1962), Lissia-Frau and Casu (1968), Besseau and Faliex (1990, 1994), Besseau (1991), Besseau and Bruslé-Sicard (1995) and Kraljević et al. (1995, 1996) also found that this species displays protandric hermaphroditism in different areas of the Mediterranean Sea. The scarcity of individuals with both developed ovarian and testicular tissues in the samples studied indicates a rather brief transitory phase between sexes for each individual. The absence of males in the largest size classes implies that sex conversion is obligatory for all fish.

In the Canarian archipelago, the reproductive season of the striped seabream extends from June to November, with maximal gonadal activity in August–September. According to Wootton (1990), temperature appears to be the most important environmental factor among those that may influence the reproduction of fishes. The species in this study spawns when the sea temperature reaches its highest values, as has been observed for other sparids present in the Canary Islands such as the pink dentex, *Dentex gibbosus* Rafinesque

1810 (Pajuelo and Lorenzo 1995) or the common pandora *Pagellus erythrinus* L. (Pajuelo and Lorenzo 1998).

Related to differences in the gonadosomatic index between reproductively active males and females, in reviewing the reproductive biology of the sparids it is noted that values of males are commonly lower than those of females. Buxton (1990) pointed out that the cost of producing sperm is thought to be less than that for producing eggs. Although the number of gametes produced does not necessarily need be a function of the size of the gonad, the difference in male and female gonadosomatic indices suggests that energy invested in gamete production by males is probably less than that invested by females.

Age at sexual maturity for males is 2 years, and 3 years for females. These results are in a good agreement with those reported for this species by Suau (1955, 1970) on the Spanish Mediterranean coast, and Ghorbel (1981) on the Tunisian coast. These authors pointed out that this species attains sexual maturity in the second year of life. The differences in the length and age at sexual maturity between males and females found in the present study may be adequately explained by the sexual change.

The real value of the instantaneous rate of natural mortality for striped seabream off the Canary Islands is between 0.30 and 0.45 years^{-1}. The values estimated following the methods of Beverton and Holt (1959) and Rikhter and Efanov (1976) must be rejected because, taking into account the age of the oldest fish found, the values of longevity that they generate are not reasonable. The value of the instantaneous rate of natural mortality reported by Kraljević et al. (1996) for this species in the Northern Adriatic ($M = 0.42$ years^{-1}) is in the range observed in the Canaries.

Life history characteristics of the striped seabream off the Canary Islands considered as important with respect to management of the species, include slow growth, longevity, relatively late maturation, large body size and relatively high adult survivorship all typically on k-selected traits (Buxton and Clarke 1991). Fisheries based on k-selected species are more susceptible to growth overfishing and stock depletion (Buxton and Clarke 1991; Booth and Buxton 1997). Ricker (1963) suggests that fish populations which include upwards of 12 age groups in appreciable quantities prior to exploitation are extremely sensitive to fishing. In addition, slow growth might result in a lower yield per unit stock, because of a lower production/biomass ratio and a slower recovery rate after overexploitation. Striped seabream also have medium to small ovaries in large individuals during the spawning season, suggesting that they are moderately fecund and that a moderate number of eggs are released during the spawning season. As a result, they may be more sensitive to heavy exploitation than species exhibiting a higher reproductive output (Smale 1988). Consequently, longevity, slow growth and a high instantaneous rate of natural mortality of this species make the stock more prone to overexploitation due to a rapid reduction in surplus production (Booth and Buxton 1997).

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