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BIOLOGY OF THE RED MULLET *MULLUS SURMULETUS* (MULLIDAE) OFF THE CANARY ISLANDS, CENTRAL-EAST ATLANTIC

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The biology of red mullet *Mullus surmuletus* was studied from collections taken off the Canary Islands between January 1991 and September 1993. Total length ranged from 12 to 33 cm, mainly between 15 and 21 cm. Males ranged from 14 to 26 cm and females from 14 to 33 cm. Females dominated the larger size-classes (>18 cm). The overall ratio of males to females was 1:2.3. The reproductive period extended from February to May, spawning peaking in March and April. The total length at 50% maturity was 16.6 cm for the whole population. The length-mass relationship for all individuals can be described by the parameters a = 0.0074 and b = 3.1826. Fish aged 0–8 years were present in the samples. The parameters of the Von Bertalanffy growth equation obtained for all individuals were: L_∞ = 35.71 cm and k = 0.22·year^{-1}. Significant differences were found in the growth parameters between males and females. The rates of total mortality Z, natural mortality M and fishing mortality F were 1.25, 0.55 and 0.70·year^{-1} respectively. The estimated total length at first capture was 15.74 cm.

Red mullet *Mullus surmuletus* (Linnaeus 1758) is a demersal marine fish that inhabits sandy and rocky substrata, usually at depths <200 m (Hureau 1986). It is distributed along the European and African coasts of the Atlantic Ocean, from the English Channel to Dakar, and around the Canary Islands. It is also widely distributed in the Mediterranean and Black seas (Ben Tuvia 1981, 1990).

Red mullet is important commercially (both as a fishery and in aquaculture, N'Da and Déniel 1993). In the Canary Islands, it is one of the main target species of the small-scale fishery, contributing approximately 15% of the total catches of demersal fish (Pajuelo 1997). The species is caught year-round, but with seasonal differences in landings.

Little information has been published on the biology of red mullet in the Atlantic Ocean. Desbrosses (1933, 1935) and N'Da and Déniel (1993) studied the reproductive cycle and N'Da (1992) and Olaso and Rodríguez-Marín (1995) described the diet. This paper provides information on the size distribution of the catches, reproduction, growth and mortality of red mullet off the Canary Islands.

MATERIAL AND METHODS

Length frequency data (n = 43 764) were obtained from red mullet collected fortnightly between January 1991 and September 1993 from small-scale fleets working from south-west of Gran Canaria (Fig. 1). Fish were caught with traps deployed on the sea bed for 6–12 days at depths of between 3 and 165 m.

A subsample was taken from each sample for biological examination (n = 1 215). Total length (*TL*) was measured to the nearest millimetre and total body mass (*TM*) was recorded to the nearest 0.1 g. Sex and stage of maturity were then determined macroscopically and gonad mass (*GM*) was taken to the nearest 0.01 g. The stages of maturation were classified as follows: I, immature; II, resting; III, ripe; IV, ripe and running; V, spent. Sagittal otoliths were removed, cleaned and stored dry in labelled vials.

The sex ratio was analysed by size-class. The spawning season was determined by following the monthly evolution of the gonadosomatic index (*GSI*), according to Anderson and Gutreuter (1983):

$$GSI = 100\ GM\ /\ TM.$$

For estimation of the length at sexual maturity (length at 50% maturity), a logistic function was fitted to the proportion of mature individuals (Stages III, IV and V) by size-class, using a non-linear regression (Saila *et al*. 1988):

$$P = a\ /\ \{1 + [(a - b)\ /\ b]\ [\exp(-cl)]\} \quad ,$$

where P is the proportion of mature individuals in each size interval and l is the mean length of the interval. The relationship between *TL* and *TM* was established by linear regression (Ricker 1973), both for males and females separately and for the whole population.

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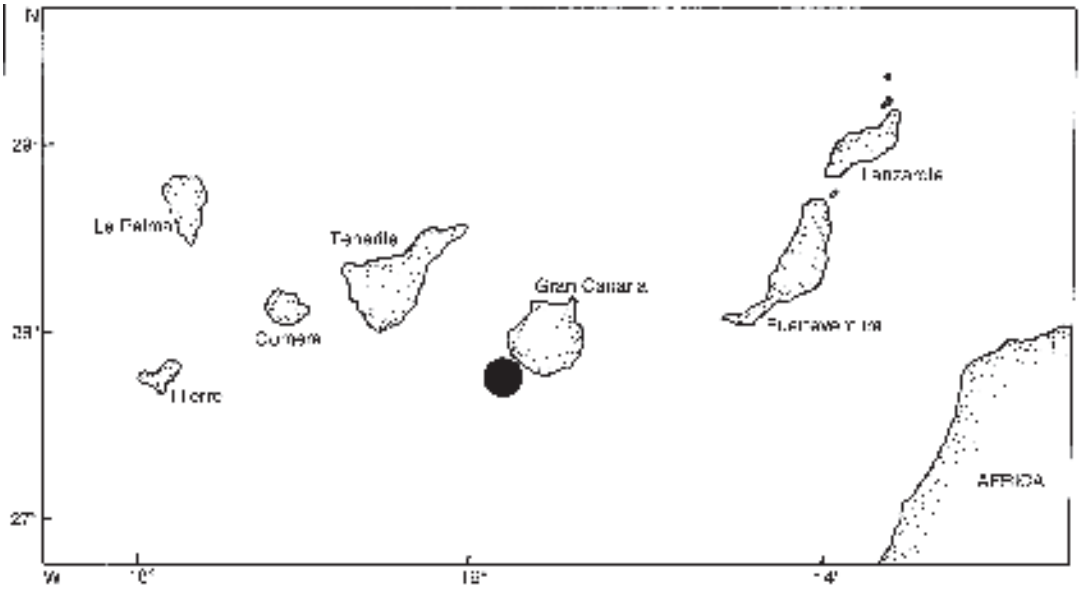

Fig. 1: Location of sampling area in the Canary Islands

Whole otoliths were placed in a blackened-bottom watch glass containing glycerin and examined under a compound microscope (15×) with reflected light. Counts for each specimen were performed twice by the senior author, approximately six months apart, without knowledge of the length of the specimen. The readings for a given otolith were accepted only if two agreed. An index of average percent error (*APE*), following Beamish and Fournier (1981), was used to compare the precision of age determination. January was used as the birthdate for the assignment of age-classes. Age was validated indirectly by examining the monthly changes in the appearance of the margins of the otoliths (Morales-Nin 1987). A Von Bertalanffy growth curve was fitted to the length-at-age data by means of Marquardt's algorithm for non-linear least-squares parameter estimation (Saila *et al.* 1988). The growth parameters obtained for males and females were compared statistically by means of Hotelling's T^2-test (Bernard 1981). The growth performance index (Φ, Munro and Pauly 1983) was used to compare growth parameters of the present study with those reported for the same species elsewhere.

Length frequency data were converted to age frequencies using the estimated Von Bertalanffy growth parameters (Pauly 1983, 1984). The rate of total mortality (Z) was calculated from the length-converted catch curve using the program ELEFAN (Gayanilo *et al.* 1988). The rate of natural mortality (M) was determined from the equation of Pauly (1980). Following estimation of Z and M, the rate of fishing mortality (F) was estimated from $F = Z - M$. The length at first capture was estimated from the selection ogive generated from the length-converted catch curve (Pauly 1984).

RESULTS

Size distribution

The total length of red mullet collected during the sampling period ranged between 12 and 33 cm, mainly from 15 to 21 cm (Fig. 2). From January to August, fish 17–21 cm dominated the catches, and thereafter, smaller fish (12–16 cm) appeared in the catches. The number of fish in the catches decreased during summer (June-August).

Reproduction

Of the total number of fish examined, 235 (19.4%) were males and 541 (44.5%) were females. The re-

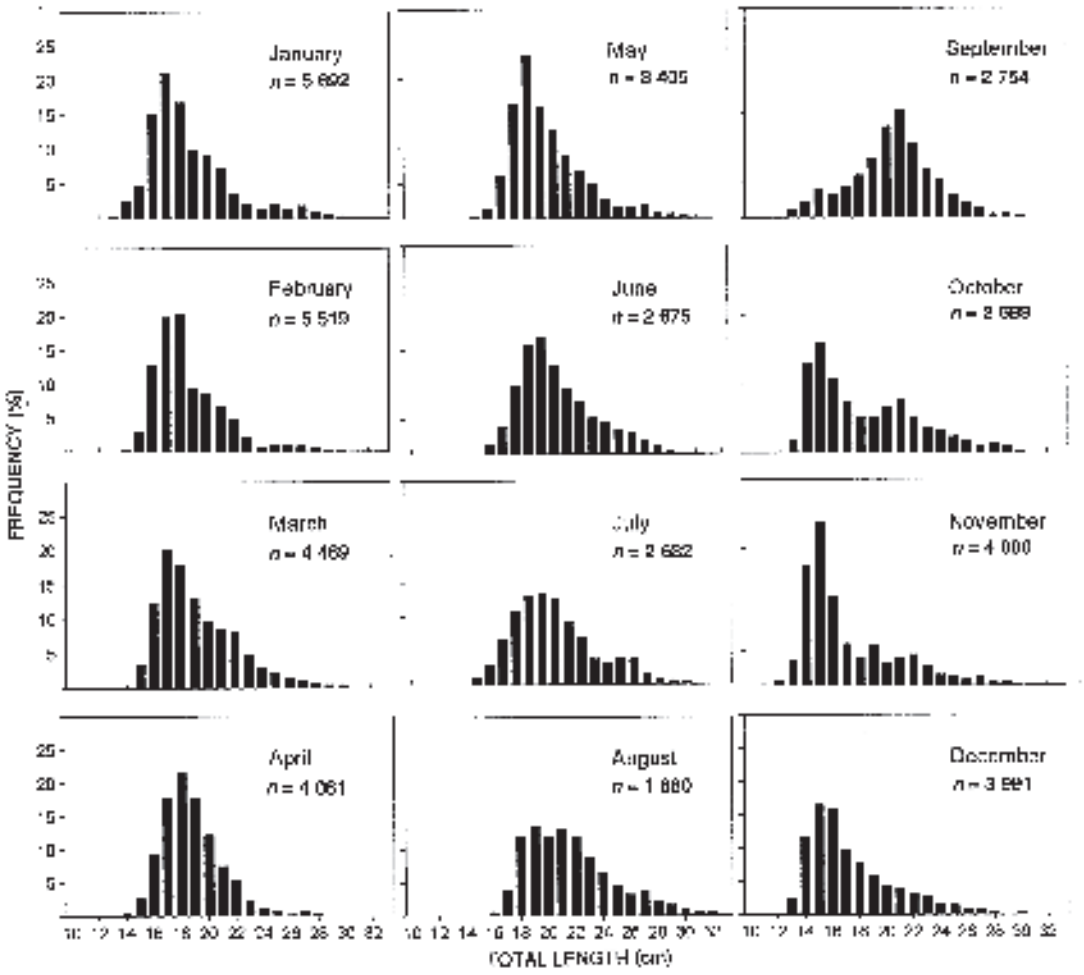

Fig. 2: Mean monthly length frequency distribution of *M. surmuletus* off the Canary Islands

maining 439 (36.1%) fish were mostly immature, having thin and translucent gonads, whose sex could not be determined macroscopically. The overall ratio of males to females was 1:2.3. A χ^2-test revealed a significant departure from unity ($p < 0.05$). Most fish <15 cm were immature (Fig. 3). Females ranged between 14 and 33 cm and dominated the larger size-classes; males were smaller, ranging between 14 and 26 cm (Fig. 3). Values of *GSI* were higher for females than for males (Fig. 4). The highest values of *GSI* for both sexes were between February and May, peaking between March and April.

There was no significant difference in the length at 50% maturity between males and females (ANCOVA, $p > 0.05$). The sexual maturity ogive for all the individuals is depicted as follows:

$$P = 99.04 / \{1 + [(99.04 - 0.000025) / 0.000025] [\exp(-0.9180\, l)]\} .$$

The total length at which 50% maturity was reached was 16.6 cm.

Growth

Analysis of covariance indicated significant differences between the length-mass relationships of the

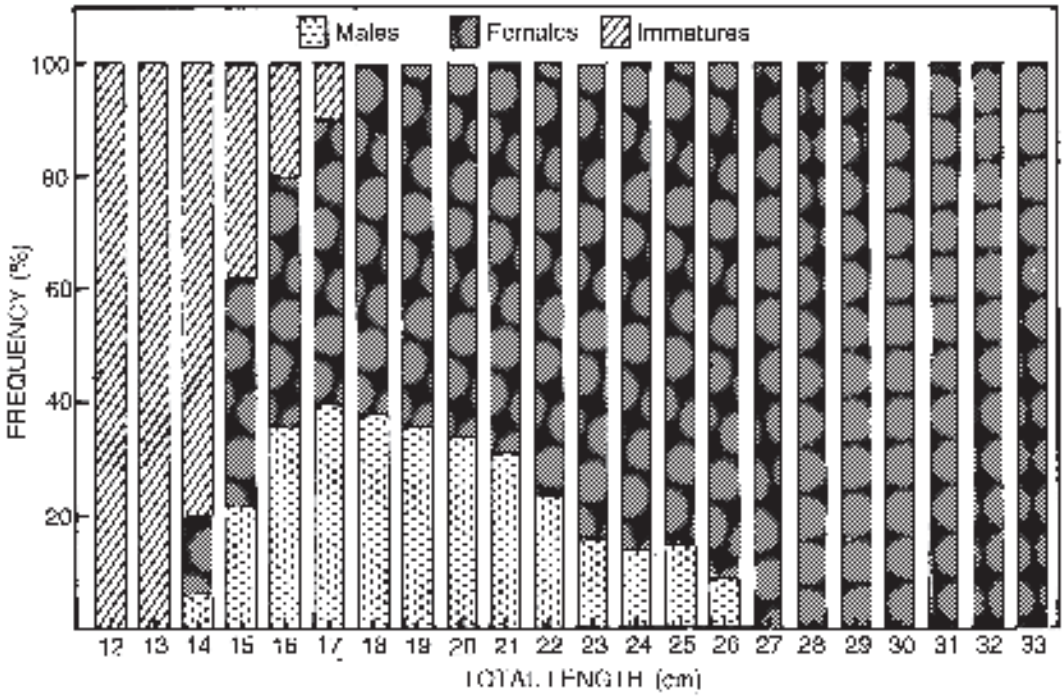

Fig. 3: Monthly sex ratios by length-class of *M. surmuletus* off the Canary Islands

two sexes (Table I).

In all, 88% of the otoliths were readable, and a low *APE* value of 3.0% was achieved. Opaque edges appeared more frequently between May and October, mainly in July and August (Fig. 5). Two rings, one translucent and one opaque, were deposited annually. One false ring was identified in the nucleus of the otoliths.

Fish of ages 0–8 years were present in the samples (Table II). There were significant differences in the mean length-at-age between males and females ($p < 0.05$). The parameters of the Von Bertalanffy growth equation determined for males, females and all individuals are shown in Table III. The growth curve obtained for all fish is presented in Figure 6. Significant differences were found between the growth of males and females ($T^2 = 92.63 > T_0^2 = 11.76$). The value of the growth performance index (Φ) obtained for the whole population was 2.44.

Mortality rates and length at first capture

The rate of total mortality (Z) estimated from the

Table I: Parameters of the length-mass relationship for males, females and all individuals of *M.surmuletus* off the Canary Islands

Parameter	Value				
	a	*b*	*c*	r^2	*n*
Males	0.0128	2.99021	0.10420	0.989	235
Females	0.0074	3.1791	0.03314	0.961	541
All fish	0.0074	3.1826	0.02134	0.988	1 215

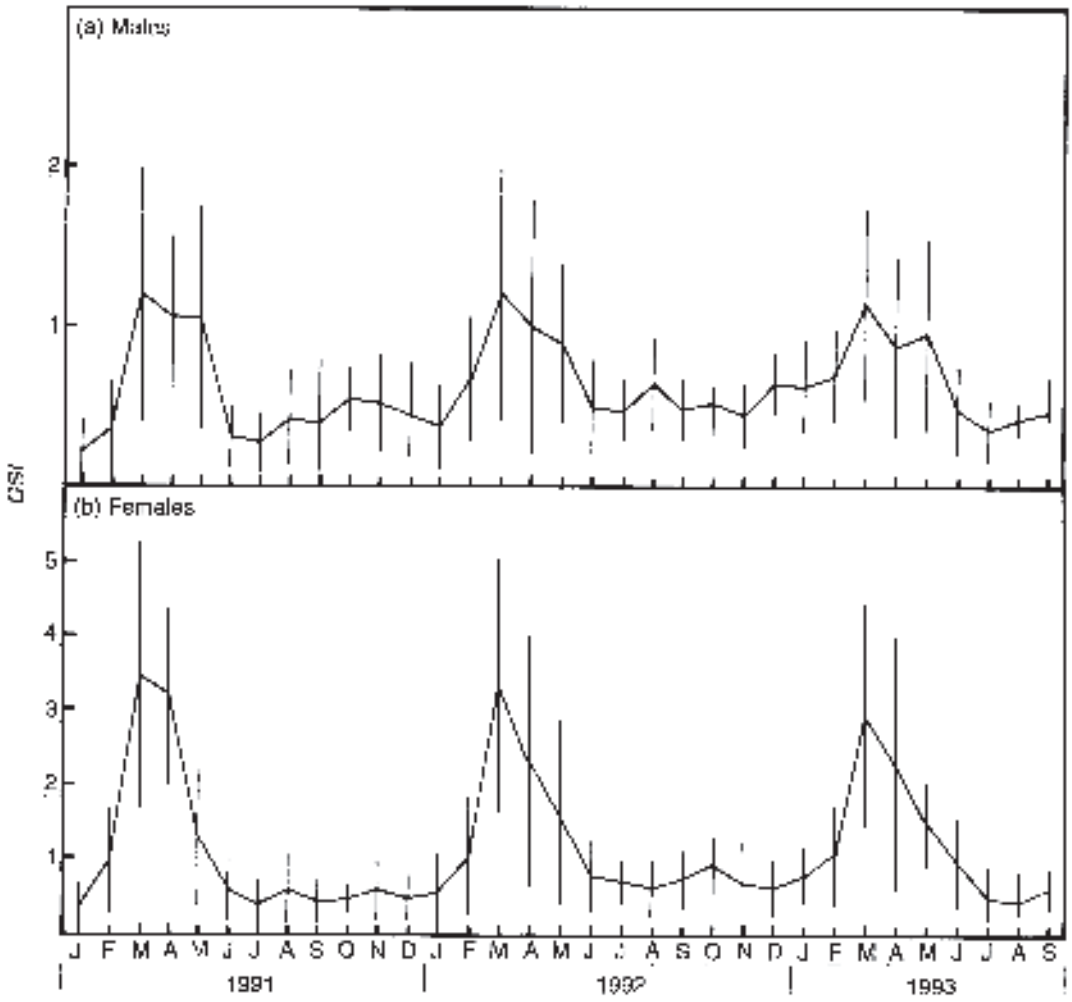

Fig. 4: Monthly change in the gonadosomatic index (*GSI*±*SD*) for (a) males and (b) females of *M. surmuletus* off the Canary Islands

length-converted catch curve (Fig. 7) was 1.25·year^{-1}. The natural mortality rate (M) was 0.55·year^{-1}, giving a fishing mortality (F) of 0.70·year^{-1}. Length-at-first-capture estimated from the selection ogive was 15.74 cm.

DISCUSSION

Highest concentrations of red mullet off the Canary Islands are found between 10 and 60 m deep, and they consisted mainly of 15–21 cm fish of between 0 and 2 years of age. The same features have been observed by Gharbi and Ktari (1981) and Reñones *et al*. (1995) for red mullet in Tunisian and Majorcan waters, where they are found at depths between 30 and 90 m and more than 90% of the fish are 0–3 years old.

Off the Canary Islands, proportionately larger red mullet were caught between January and August than between September and December, when small

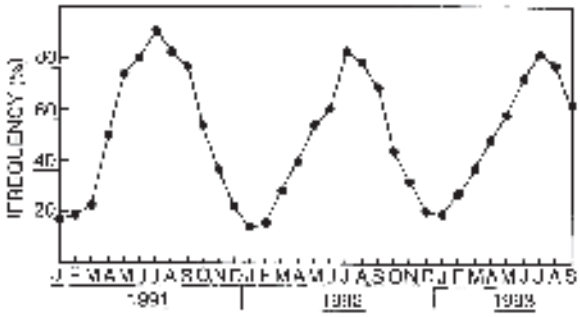

Fig. 5: Monthly frequency of otoliths with opaque edges for *M. surmuletus* off the Canary Islands

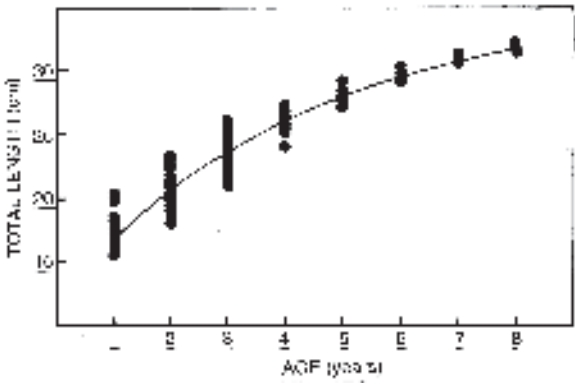

Fig. 6: Von Bertalanffy growth curve fitted for *M. surmuletus* off the Canary Islands

(<15 cm), age-0 fish appeared in the catches. These seasonal differences in the length distribution of the catches may be explained by the introduction of recruits to the fishery during autumn, and the high concentrations of spawning adults in spring. In Tunisian and Majorcan waters, Gharbi and Ktari (1981) and Reñones *et al*. (1995) observed concentrations of juvenile red mullet close to the coast in summer and autumn, and a migration towards shallow waters by mature adults in spring and summer. Camiñas *et al*. (1990) reported that *Mullus surmuletus* migrate from shallow to deep waters in the Spanish South Mediterranean region after breeding. These migrations explain why the landings are seasonal all-year-round in that region.

The red mullet off the Canary Islands is a gonochoristic species, which seems to be characteristic of red mullet elsewhere (Desbrosses 1933, 1935, Bougis 1952, Hashem 1973, Andaloro 1982, Camiñas *et al*. 1990, Bertrand 1991, Morales-Nin 1991, N'Da and Déniel 1993, Reñones *et al*. 1995). The sex ratio found in this study is unbalanced in favour of females, as has been reported for red mullet in the Mediterranean (Andaloro 1982, Camiñas *et al*. 1990, Morales-Nin 1991). The dominance of females may be attributable to the differences in the spatial distribution between males and females, as suggested by Lozano-Cabo (1983) and Camiñas *et al*. (1990) for this species.

Off the Canary Islands, the breeding season of red mullet extends from February to May, with maximal gonad activity in March and April. Spawning of red mullet is between April and July in the English Channel (Desbrosses 1933, 1935, N'Da and Déniel 1993) and in the Mediterranean between March and August (Hashem 1973, Andaloro 1982, Morales-Nin 1991, Reñones *et al*. 1995). Spawning of red mullet seems to be related to water temperature. Optimum temperature for spawning is 19–22°C, which typically is found during spring around the Canary Islands and during summer in the North-East Atlantic and the Mediterranean.

Red mullet around the Canary Islands attain sexual maturity during their first year of life, at around 16.6 cm. Similarly, in the Mediterranean they attain sexual maturity between the first and the second years of life (Hashem 1973, Andaloro 1982, Sánchez *et al*. 1983, Camiñas *et al*. 1990, Bertrand 1991, Morales-Nin 1991, Reñones *et al*. 1995).

The alternative pattern of translucent and opaque

Table III: Parameters of the Von Bertalanffy growth equation for males, females and all individuals of *M. surmuletus* off the Canary Islands

Parameters	Value				
	L_∞ (cm)	k(·year^{-1})	t_0 (year)	r^2	n
Males	29.19	0.23	–1.76	0.94	210
Females	36.93	0.19	–1.98	0.98	221
All fish	35.71	0.22	–1.84	0.98	449

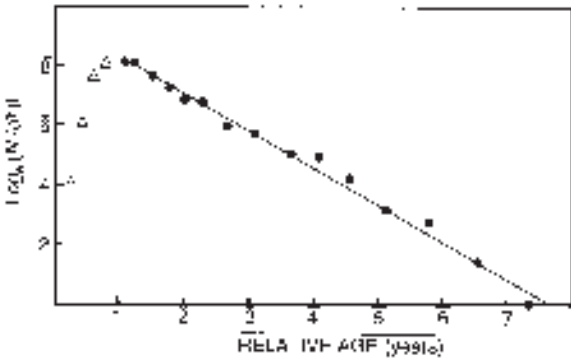

Fig. 7: Length-converted catch curve for *M. surmuletus* off the Canary Islands. The initial data points (triangles) were not used in the regression

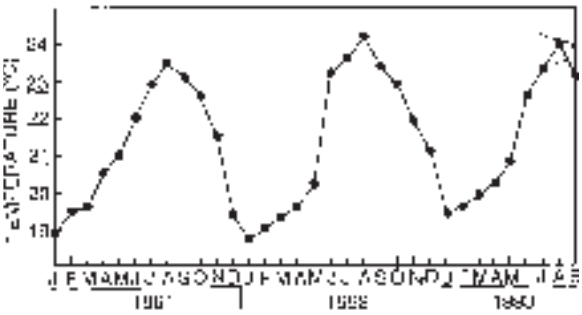

Fig. 8: Monthly sea surface temperatures off the Canary Islands

zones was easily distinguishable on the otoliths of the red mullet off the Canary Islandss. The opaque zone is formed when SST is highest (Fig. 8) and food is abundant (Hernández-León 1988), and the translucent ring is formed during the spawning season and when SST is lowest. The false ring observed in the nucleus of the otoliths is a demersal ring, which is formed when young red mullet migrate from a pelagic to a demersal habitat. The presence of this ring has also been reported for red mullet in different areas of the Mediterranean sea (Sáncgez *et al.* 1983, Morales-Nin 1991, Reñones *et al.* 1995).

The oldest red mullet examined off the Canary Islands was 8 years old, but fish 5 years and older were scarce in the landings. In the Mediterranean, Andaloro (1981, 1982) and Sánchez *et al.* (1983) found that red mullet can attain an age of 7 years. In that region, Andaloro and Giarritta (1985) and Reñones *et al.* (1995) recorded fish up to 6 years old, and Bougis (1952), Hashem (1973), and Morales-Nin (1991) recorded them up to 3, 5 and 4 years old respectively. These differences between ages should be attributable to differences in the length of the largest fish sampled in the various studies.

Growth is rapid in red mullet off the Canary Islands, with males having a slightly faster growth rate than females. This difference in growth between sexes is characteristic of the species (Bougis 1952, Hashem 1973, Andaloro 1981, 1982, Andaloro and Giarritta 1985, Moralis-Nin 1991, Reñones *et al.* 1995). The overall growth rate of red mullet around the Canary Islands is similar to those reported elsewhere for the species, except in Catalonia, where it appears slower (Table IV).

It has been demonstrated that the capture of fish prior to attaining sexual maturity can result in a depletion of the spawner biomass and therefore recruitment. Given that the length at first capture reported herein is smaller than the length at sexual maturity, it may be necessary to change the current fishing strategy for red mullet around the Canary Islands in order to avoid recruitment overfishing (Pajuelo 1997). However, a study of the population dynamics of this resource is required to determine appropriate management recommendations.

Table IV: Parameters of the Von Bertalanffy growth curve and value of the growth performance index of *M. surmuletus* in different areas

Locality	Size range (cm)	Parameter				Source
		L_∞ (cm)	k(·year^{-1})	t_0 (year)	Φ	
Catalonia	5–26	35.52	0.11	–3.65	2.06	Sánchez *et al.* (1993)
Tunisia		21.51	0.50	–0.12	2.36	Gharbi and Ktari (1981)
Majorca	9–27	29.76	0.24	–2.64	2.32	Morales-Nin (1991)
Majorca	10–32	31.28	0.21	–2.35	2.31	Reñones *et al.* (1995)
Canaries	12–33	35.71	0.22	–1.84	2.44	This study

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