Aspects of the life history of the salema, *Sarpa salpa* (Pisces, Sparidae), off the Canarian Archipelago (central-east Atlantic)

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Synopsis

Life history of the salema, *Sarpa salpa*, off the Canarian archipelago was studied from samples collected between January 1998 and December 1999. Fish ranged from 119 to 452 mm in total length and from 24.9 to 1491.7 g in weight. The species was characterized by a protandric hermaphroditism. The overall sex ratio was unbalanced in favour of males (1 : 0.41). The reproductive season extends from September to March, with a peak in spawning activity in December–January. Males reached maturity at a smaller length (226 mm, 2 years old) than females (294 mm, 3 years old). Males, females and all fish showed an isometric growth. The morphometric relationship between length and mass for the whole population was described by the parameters: a = 0.0000134 and b = 3.01. A concentric pattern of opaque and translucent zones was readily distinguishable on the otoliths. Two rings, one opaque and one translucent, were laid down each year on the otoliths; the opaque zone was formed during the summer months, and the translucent zone during the winter months. Individuals aged 0 to 11 years were found. The parameters of the von Bertalanffy growth equation for all individuals were: $L_\infty = 479$ mm, $k = 0.212$ year^{-1}, and $t_0 = -1.08$ year.

Introduction

In the Canary Islands (Central-east Atlantic), the family Sparidae is represented by 10 genera, one of which is the genus *Sarpa* Bonaparte, 1831. The salema, *Sarpa salpa* (Linnaeus 1758), is the only species of this genus recognized to date (Bauchot & Hureau 1986, 1990).

The salema is a demersal marine fish living in groups on sandy bottoms and seagrass beds at depths ranging from 0 to 70 m. It is distributed in the Eastern Atlantic (from the North Sea to Cape of Good Hope; in the Madeira, the Canaries and Cape Verde Islands; and in the Mediterranean and Black seas) and in the Western Indian Ocean (from Mozambique to Cape of Good Hope) (Smith & Smith 1986, Bauchot & Hureau 1990).

Although the salema has been extensively studied in the Mediterranean sea and in the Indian Ocean, no information on biology of this species has been published in the Atlantic Ocean. The aim of the present work is to determine the sexuality, reproduction, age, and growth of the salema off the Canary Islands. This species is of great commercial interest in the Canary Islands, where it constitutes one of the most important fishes taken by the artisanal fleet (Méndez-Villamil 2001). The population parameters of the salema from the Canary Islands are investigated in this study because the findings may be used to develop a management strategy and will provide an insight into the life history of the species. No data are known on the salema in the Atlantic Ocean with exception of the spawning period in the Cape Verde Islands (Bauchot & Hureau 1986).

Materials and methods

Samples of salema (N = 1125) collected fortnightly from the commercial catches of the artisanal fleet

between January 1998 and September 1999 were studied. Fish were caught with entangling nets at depths of 0–10 m off Gran Canaria (Canary Islands).

Analysis of the samples was completed immediately after landing. Total length (TL) was measured to the nearest 1 mm, and total weight (TW) to the nearest 0.1 g. The sex and the stage of maturation of all specimens were recorded by macroscopic examination of the gonads. The weight of the gonads was measured to the nearest 0.01 g. The stages of maturation were classified as follows: I = immature; II = resting; III = ripe; IV = ripe and running; and V = spent (Holden & Raitt 1975). Finally, otoliths (sagittae) were removed, cleaned, and stored dry.

The sex ratios (males : females) for the entire sample and for different size classes (10 mm) were estimated. Monthly sex ratios were tested statistically for significant deviations from the expected 1 : 1 ratio with a chi-square test ($\alpha = 0.05$). The reproductive period was determined following the monthly development of the maturity stages and the development of the gonadosomatic index (Anderson & Gutreuter 1983). To estimate mean length at first maturity (length at first maturity was defined as the smallest length interval in which 50% of the individuals were sexually mature) the fraction of mature fish per 10 mm length intervals was fit to the logistic function by nonlinear regression (Mardquart method), using the software program Fishparm (Saila et al. 1988). Only fish sampled during the spawning season were considered for the mean length at first maturity. Fish were considered sexually mature if they were in gonad stage III (ripe), IV (ripe and running) or V (spent).

Total length–total weight relationship was calculated by applying exponential regression (Ricker 1973). The allometric index values obtained were compared with the expected values with a Student's t-test.

Age was determined by interpreting growth rings on the otoliths. Whole otoliths were immersed fully in glycerine and read with a compound microscope (12×) using reflected ligth. Counts for each specimen were made on the postrostral area. As a rule, each otoliths was read twice, and only coincident interpretations were accepted. An index of average percent error, developed by Beamish & Fournier (1981), was used to compare the precision of age determinations. To assess the annual nature of otoliths rings, the seasonal development of the marginal edge of the otolith was determined. Data during 2 year period were pooled to remove the interannual variability. Once the

ring were considered to be annual, each specimen was assigned to a year class taking into account the date of capture, the annuli counts, their formation period and the 1st January as the start of age class 0. The difference between the date of capture and 'birthdate' helped the reader to estimate the annual fraction elapsed since the last 'birthdate', and the annual fraction was added to the number of complete hyaline zones read in the otoliths (Gordoa & Molí 1997).

The von Bertalanffy growth equation was used to describe the growth of salema and was fitted to the observed length-at-age, instead of the mean length-at-age so frequently used, to show the individual growth variability. The von Bertalanffy growth equation was fitted to the length at age date obtained from otolith reading by means of Mardquart method using Fisat program (Gayanilo et al.[1], Gayanilo & Pauly[2]).

The growth performance index (Φ) was estimated in order to compare the values of the growth parameters obtained in the present paper with those reported by van der Walt & Beckley (1997) for the same species. This index was calculated as follows (Munro & Pauly 1983): $\Phi = 2 \log L_\infty + \log k$.

Results

Of the 1125 fish examined, 649 (57.7%) were males, 267 (23.7%) females, and 54 (4.8%) intersexuals. The sex of the remaining 155 (13.8%) individuals could not be identified macroscopically because they were immature and had very thin, translucent gonads. The maximum and minimum values of the total length and total weight for immatures, males, females and intersexuals individuals are presented in Table 1.

The overall ratio of males to females (1 : 0.41) was significantly different from 1 : 1 ratio ($\chi^2 = 159.65 > \chi^2_{t\,1,0.05} = 3.84$). A high percentage of individuals smaller than 160 mm could not be sexed. Males appeared in the range 150 to 380 mm and were predominant between 180 and 300 mm; females appeared in the range 220 to 450 mm and were clearly predominant from 310 to 450 mm. Hermaphrodites were intermediate in size between males and females (230–350 mm)

[1] Gayanilo, F.C., P. Sparre & D. Pauly. 1996. FAO-ICLARM stock assessment tools (Fisat). User's manual. FAO Computerized Information Series (Fisheries), no 8. FAO, Rome. 126 pp.

[2] Gayanilo, F.C. & D. Pauly. 1997. FAO-ICLARM stock assessment tools (Fisat). Reference manual. FAO Computerized Information Series (Fisheries), no 8. FAO, Rome. 262 pp.

(Figure 1). Sex ratios of males and females by size intervals departed significantly from 1 : 1 ratio for most classes, except for the middle ones (280–310 mm).

Males and females with ripe gonads (stage III) were recorded between September and January; ripe and running fish (stage IV) appeared in October and became dominant in November and December; spent fish (stage V) were recorded from January to March (Figure 2). The gonadosomatic index showed the same temporal variation pattern for males and females. Lower values for males than for females were observed. The highest values were observed between October and February, with a maximum in December–January (Figure 3).

Table 1. Maximum and minimum values of the total length and total weigth for immatures, males, females and intersexuals of *S. salpa* off the Canary Islands.

	Total length (mm)		Total weight (g)	
	Minimum	Maximum	Minimum	Maximum
Immatures	119	245	24.9	218.91
Males	157	380	57.3	798.0
Females	221	452	152.6	1491.7
Intersexuals	237	353	188.1	600.6

Significant difference in length at first maturity was found between males and females (t-test, $t = 7.28 > t_{0.05,45} = 1.65$). Fifty percent of males and females matured at 266 and 294 mm, respectively (Figure 4). Individuals smaller than 160 mm showed little evidence of sexual activity.

The parameters of the total length to total weight relationship for males and females separately, and for the population as a whole, are given in Table 2. Significant difference in the allometric coefficient of the regression was found between sexes (t-test, $t = 8.17 > t_{0.05,378} = 1.64$). Males and all fish showed isometric growth. Females showed negative allometric growth.

Of the total otoliths examined, 960 (85.3%) were readable. The value of the index of average percent error was 3.1%. Annuli were apparent, whereas non-annual marks usually were not. Edge zone analysis showed that one annulus was formed per year (Figure 5). The percentage of otoliths with opaque edges was high in the months from May to October, and between June and August in particular.

Individuals 0 to 11 years old were present in the samples. The oldest fish examined was a 452 mm total length female estimated to be 11 years old, and the
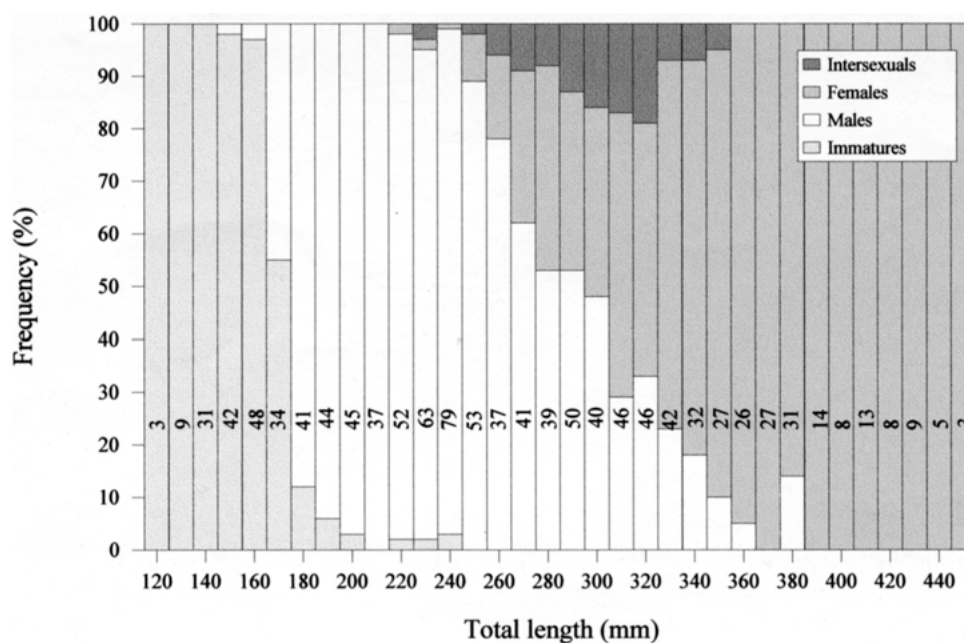

Figure 1. Frequency of males, females, intersexuals and immatures, and number of individuals by length class of *S. salpa* off the Canary Islands.
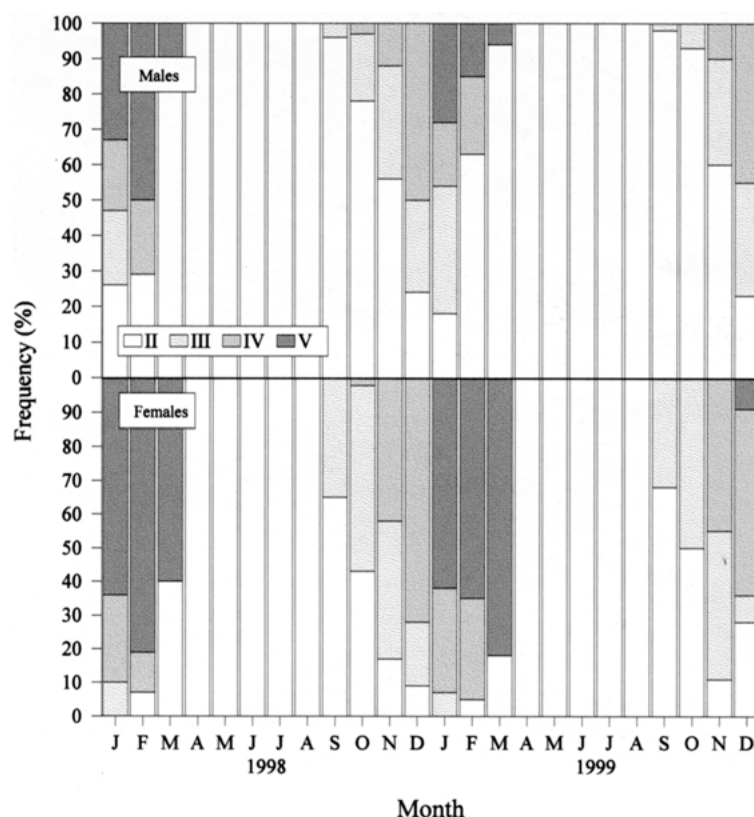
Figure 2. Monthly development of the maturity stages for males and females of *S. salpa* off the Canary Islands.

oldest male was 8 years old with a total length of 380 mm. During the second year of life, fish attained over 50% of their maximum observed length. The age–length relationship for all individuals and the calculated growth parameters for males, females and all fish are shown in Tables 3 and 4. Von Bertalanffy's growth curve fitted the data reasonably well, considering that individual observations of length at age were used instead of the mean length at age (Figure 6). The coefficients of determination from each curve fitted show that the von Bertalanffy model explained 98% of the growth pattern of the males, 97% of the females, and 98% of all individuals (Table 4). Significant differences in the growth parameters were found between males and females (Hotelling's T^2-test, $T^2 = 93.7 > T_0^2{}_{0.05,3,786} = 7.85$). The predicted length at age of females was greater than that of males and estimates of asymptotic length were higher for females than for males. The value of the growth performance index obtained for all fish was $\Phi = 4.56$ (L_∞ converted into fork length).

Discussion

The salema of the Canary Islands exhibits hermaphroditism. The presence of individuals with ovotestes and the predominance of males at smaller sizes suggest that this species displays protandric hermaphroditism. This characteristic has also been pointed out for the same species in the Mediterranean Sea (Lissia-Frau 1966, 1968, Lissia-Frau & Casú 1968) and in the Western Indian Ocean (van der Walt & Mann 1998). The presence of hermaphrodites in a wide size range (230–350 mm) suggests that the sex conversion does not occur simultaneously for all males (Alekseev 1983). The scarcity of individuals with both developed ovarian and testicular tissues in the samples 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 essential for all fish.

The sex structure of the population, with a predominance of males, is mainly determined by the nature of
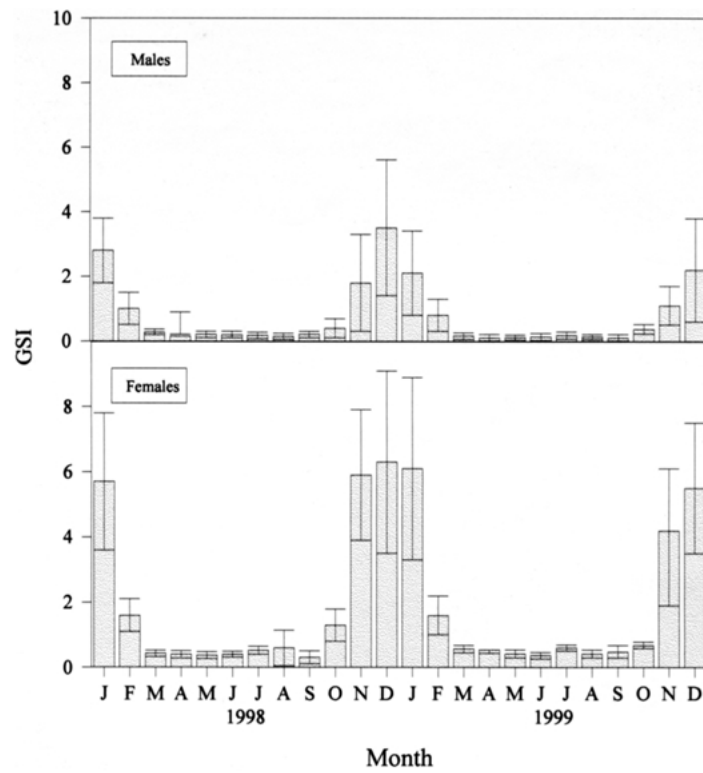
Figure 3. Monthly development of the gonadosomatic index (GSI) for males and females of *S. salpa* off the Canary Islands.
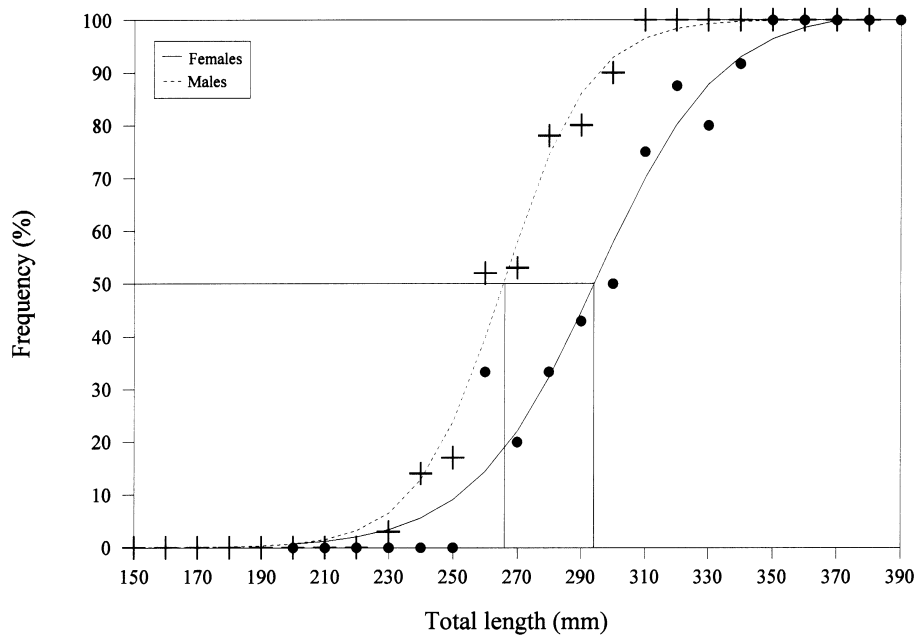

Figure 4. Sexual maturity ogives for males and females of *S. salpa* off the Canary Islands.

the sexual change. The predominance of males has also been observed for this species in the Western Indian Ocean (Joubert 1981, van der Walt & Mann 1998). Related to this, Pollock (1985) indicated that the sex ratios of protandric sparids may be skewed towards the males.

In the Canarian archipelago, the reproductive season of the salema extends from September to March, with maximal gonadal activity in December–January. Of the environmental factors that may influence the reproduction of fishes, temperature appears to be the most important (Wootton 1990). This is apparent for the species in this study and has also been demonstrated in other sparids present in the Canary Islands, such as *Dentex gibbosus* (Pajuelo & Lorenzo 1995), *Pagellus acarne* (Pajuelo & Lorenzo 1994), *Pagellus erythrinus* (Pajuelo & Lorenzo 1998) and *Pagrus pagrus* (Pajuelo & Lorenzo 1996). The peak of spawning of the salema in winter months has also been pointed out for the species in the Mediterranean Sea

(Anato et al. 1983, Anato & Ktari 1983, Antolic et al. 1994) and in the Western Indian Ocean (Joubert 1981, van der Walt & Mann 1998). The protracted spawning season of *S. salpa* recorded in this study is suggestive of serial spawning behaviour. Similar results were found by van der Walt & Mann (1998).

Age at maturity for males is 2 years and for females 3 years. These results are in good agreement with those reported for the same species in the Western Indian Ocean (Joubert 1981, van der Walt & Mann 1998). These authors pointed out that salema attains sexual maturity between the end of the first year of life and the second year. 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 isometry of the total length–total weight relationship for the whole population agrees with the result of Dulcic & Kraljevic (1996) for the salema of the Adriatic Sea. The difference in the curves of the size–weight relationship between males and females is due to the difference in length distributions of the two sexes as a consequence of the sexual pattern.

The oldest age estimate obtained in this study is 11 years and the phenomenon of stacking is not evident. Otoliths of the salema off the Canary Islands show the ring pattern common to teleost fishes, with hyaline rings that alternated with opaque rings, attributed to slow and fast growth periods, laid down around

Table 2. Parameters of the length–weight relationship for males, females and all *S. salpa* off the Canary Islands and the possibility of isometry tested by Student t-test $^*(t > t_{0.05,n>250} = 1.65)$.

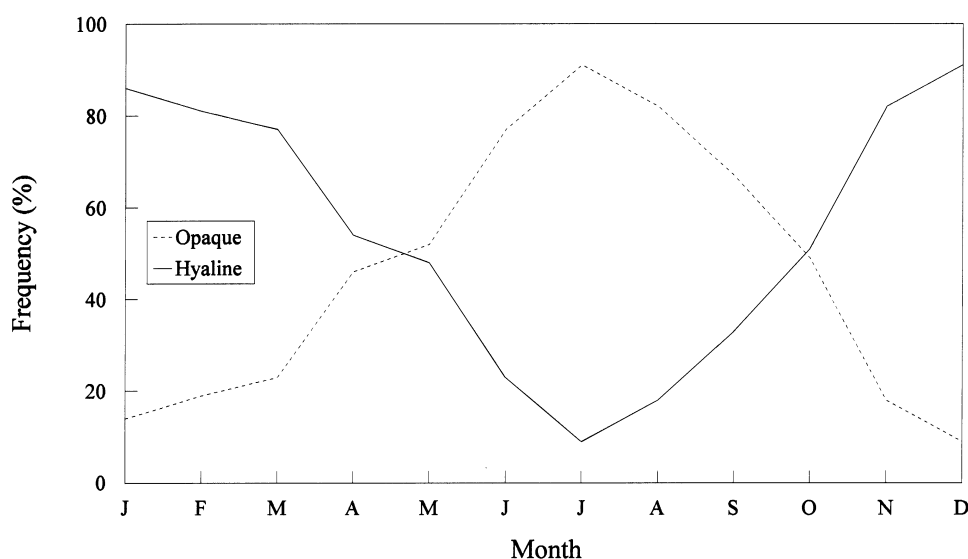|	a	b	sd (b)	n	r^2	t-test
Males	0.0000164	2.976	0.0204	649	0.971	1.17*
Females	0.0000183	2.957	0.0161	267	0.939	2.67
All fish	0.0000134	3.011	0.0098	1125	0.988	1.12*

Figure 5. Monthly percentage of otoliths with opaque and hyaline edge for *S. salpa* off the Canary Islands.

Table 3. Age at length for all *S. salpa* off the Canary Islands.

Size (mm)	Age class (years)											
	0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
120	1											
130	5											
140	24											
150	32	8										
160	30	15										
170	9	21										
180	1	27										
190		35	5									
200		29	12									
210		11	21									
220		7	33	1								
230		4	47	5								
240		3	59	9								
250			38	15								
260			17	19	1							
270			9	32								
280			1	34	4							
290				43	7							
300				26	13	1						
310				13	29	4						
320				4	39	3						
330					34	7	1					
340					17	14	1					
350					6	18	3					
360					2	10	4					
370						6	10					
380						1	7	2				
390							1	1				
400								1				
410								1	2			
420									1	1		
430											1	
440											1	
450												1
n	102	160	242	201	152	64	27	5	3	1	2	1
x	128	181	238	285	322	353	377	397	413	423	434	446
sd	17	31	26	27	24	16	12	9	4	—	2	—

Table 4. Parameters of the von Bertalanffy growth equation for males, females and all *S. salpa* off the Canary Islands.

	L_∞ (mm)	k (year^{-1})	t_0 (year)	n	r^2
Males	445	0.229	−1.022	649	0.981
Females	497	0.203	−1.264	267	0.968
All fish	480	0.210	−0.973	960	0.982

an opaque nucleus (Williams & Bedford 1974). The maximum percentage of otoliths with hyaline ring at the edge during the winters months could be related to physiological stress during the spawning of the species.

Nevertheless, because these rings are present in juveniles as well as adults, they should be also related to the lowest values of sea temperature (18°C). The high percentage of otoliths with opaque ring at the edge during summer, attributed to a fast growth period, could be due to temporal variation in food resources and the highest sea temperature (24°C). The evidence presently available suggests that a seasonal temperature difference of 6°C might be sufficient to cause ring formation (Morales-Nin & Ralston 1990). During the reproductive period, the metabolic energy seems to be diverted from growth, causing the formation of thin increments
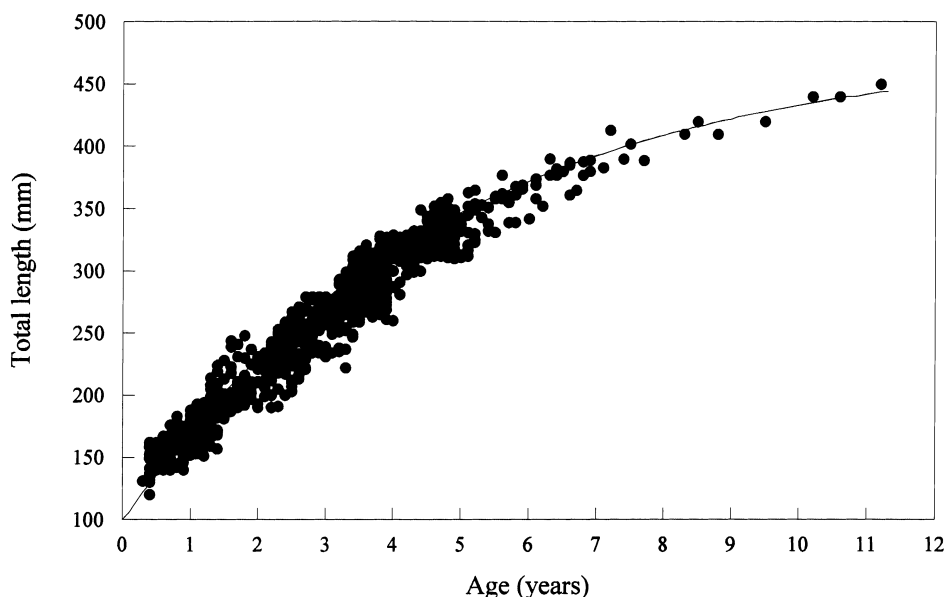
Figure 6. von Bertalanffy growth curve for all individuals of *S. salpa* off the Canary Islands.

which are in turn reflected in translucent seasonal growth rings. Similar findings have been recorded in other studies carried out in the Canarian archipelago on other sparid species, such as pink dentex, *Dentex gibbosus* (Pajuelo & Lorenzo 1995), axillary seabream, *Pagellus acarne* (Pajuelo & Lorenzo 2000), common pandora, *Pagellus erythrinus* (Pajuelo & Lorenzo 1998), red porgy, *Pagrus pagrus* (Pajuelo & Lorenzo 1996) and black seabream, *Spondyliosoma cantharus* (Pajuelo & Lorenzo 1999).

In the Canarian archipelago, the salema grows relatively fast during the first year of life, attaining approximately fifty percent of its maximum length in the second year of life. After the second year, the annual growth rate drops rapidly, since in the studied area individuals are mature by the second year of life. Hence, energy seems to be diverted to reproduction, with less energy available for somatic growth. The difference in growth between sexes, with females reaching a slightly bigger length than males at the same age, is a characteristic of the protandric species as the salema (D'Ancona 1949, Michèle & Lafaurie 1974, Febvre et al. 1975, Michèle 1977). Alekseev (1983) and Shapiro (1984) pointed out that the mean size of sex reversed fish is slightly larger than same age males. Therefore, the difference in size between males and females of the same age can not be considered as evidence of an intersexual difference in growth rates because males and females

are the same specimens at different intervals of sexual succession and, possibly, the largest males in an age group are the first to revert (Shapiro 1989). Related to this, van der Walt & Mann (1998) pointed out that during the spawning aggregation where male–male competion is strong, selective pressure may be placed on smaller males to change sex to female.

The maximum age obtained in the present study is higher than that observed in the Western Indian Ocean by van der Walt & Beckley (1997). In specimens between 30 and 270 mm fork length these authors estimated a maximum ages of 6 years. Probably, in this study the age of old specimens is underestimated due to the absence of individuals larger than 270 mm fork length. However, by calculating a growth performance index, our results showed similar growth rates to those reported in the Western Indian Ocean ($\Phi = 4.44$) by van der Walt & Beckley (1997).

Life history characteristics of the salema off the Canary Islands which are considered important with respect to management of the species include slow growth, longevity, relatively late maturation, large body size and relatively high adult survivorship (Buxton & Clarke 1991). Fisheries based on K-selected species are more susceptible to overfishing and stock depletion (Buxton & Clarke 1991, Booth & Buxton 1997). 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. Salema has also medium–small ovaries in large individuals during the spawning season, suggesting that 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). In consequence, the life history characteristics of this species make the stock more prone to overexploitation due to a rapid reduction in surplus production (Booth & Buxton 1997).

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