Age and growth of the bastard grunt (*Pomadasys incisus*: Haemulidae) inhabiting the Canarian archipelago, Northwest Africa

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Abstract—The bastard grunt (*Pomadasys incisus*) is one of the most abundant coastal demersal fishes inhabiting the Canary Islands. Age and growth were studied from samples collected between October 2000 and September 2001. Growth analysis revealed that this species is a fast growing and moderately short-lived species (ages up to seven years recorded). Length-at-age was described by the von Bertalanffy growth model (L_∞=309.58 mm; k=0.220/year; t_0=–1.865 year), the Schnute growth model (y_1=126.66 mm; y_2=293.50 mm; a=–0.426; b= 5.963), and the seasonalized von Bertalanffy growth model (L_∞=309.93 mm; k=0.218/year; t_0= –1.896 year; C=0.555; t_s=0.652). Individuals grow quickly in their first year, attaining approximately 60% of their maximum length; after the first year, their growth rate drops rapidly as energy is probably diverted to reproduction. The parameters of the von Bertalanffy weight growth curve were W_∞=788.22 mm; k=0.1567/year; t_0= –1.984 year. Fish total length and otolith radius were closely correlated, r^2=0.912. A power relationship was estimated between the total length and the otolith radius (a=49.93; v=0.851). A year's growth was represented by an opaque and hyaline (translucent) zone—an annulus. Backcalculated lengths were similar to those predicted by the growth models. Growth parameters estimated from the backcalculated sizes at age were L_∞=315.23 mm; k=0.217/year; and t_0= –1.73 year.

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The family Haemulidae consists of 16 genera (126 species), including the genus *Pomadasys.* This genus is represented by 37 species distributed around the world. Members of this family are commonly referred to as grunt (Bauchot and Huraeu, 1990). Only the bastard grunt (*Pomadasys incisus* (Bowdich, 1825)) is found off the Canary Islands. The bastard grunt is a coastal demersal fish species inhabiting marine and brackish waters along the eastern central Atlantic coasts from the Strait of Gibraltar to Angola, and also in the Canaries, Azores, and Cape Verde Islands (Bauchot and Hureau, 1990). In the Canary Islands, where the bastard grunt is one of the most abundant species, it has been observed in high densities in schools along coastal waters.

Information on the biology of the bastard grunt is not available anywhere in the world. Despite its widespread occurrence, the bastard grunt has no commercial value for its low quality meat and it is discarded in the Canarian archipelago. The need for a biologically based discard management strategy and the paucity of data available on the biology of this species have prompted an investigation into aspects of its life history. We report aspects of age and growth, which are important parameters in models for managing the population of the bastard grunt off the Canary Islands.

Materials and methods

A total of 878 individuals of *P. incisus* were collected at weekly intervals from discarded commercial catches taken between October 2000 and September 2001 off Gran Canaria (Canary Islands, central-east Atlantic, 27°57′24″N–15°35′23″W).

Each fish was measured to the nearest mm for total length (L_t) and weighed to the near 0.1 g for total body weight (W_t). Sex was assessed visually and sagittal otoliths were removed, cleaned, and stored dry for later age determination.

Age estimation was made by identifying and counting annuli following Williams and Bedford (1974). An annulus was defined as a hyaline zone formed annually in the winter season when there is low growth and an opaque zone formed annually in the summer season when there is increased growth. The whole otoliths were placed in a blackened bottom watch glass containing water and examined under a compound microscope (10×) with reflected light. Counts of the growth bands were made

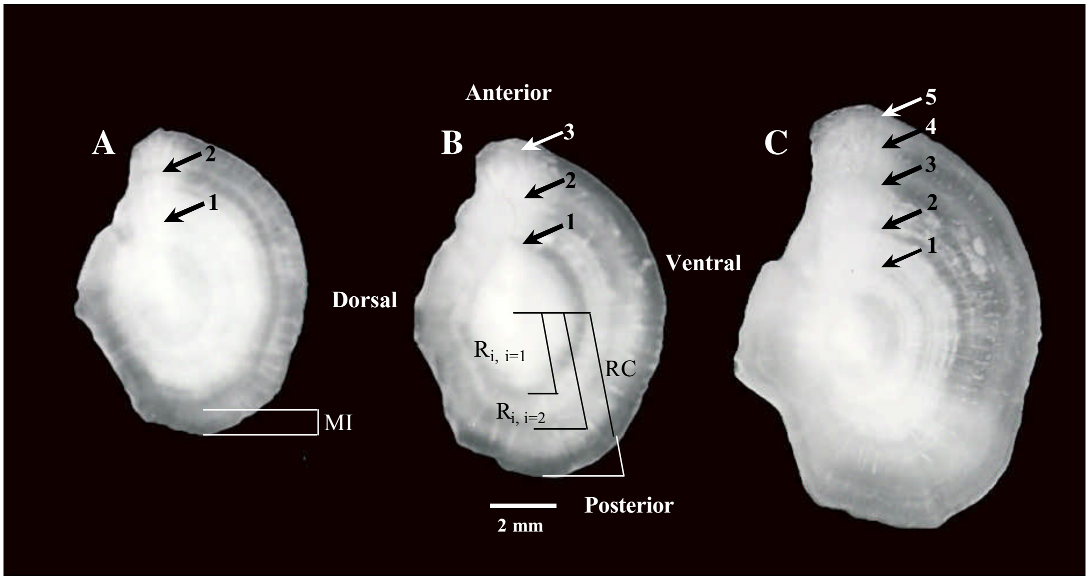

Figure 1

Saggital otoliths of *P. incisus* collected off the Canary Islands: (**A**) from a two-year-old (182 mm); (**B**) from a three-year-old (202 mm); and (**C**) from a five-year-old (265 mm) fish. *Ri* is the radius of the i^{th} band (distance from the centre of the otolith to the outer margin of the annulus), *Rc* is the radius of the otolith at capture, and MI is the marginal increment measured.

by two readers without knowledge of the size and sex of the specimens, or previous counts of the other reader. Counts were made for otoliths of each individual on two separate occasions, and only coincident readings were accepted. The same approach was used to determine the final number of bands in each specimen, and a consensus was reached between readers on the final counts. Reproducibility of the resultant age estimates was evaluated with the coefficient of variation (CV) (Chang, 1982) and the index of average percent error (IAPE) (Beamish and Fournier, 1981).

To validate that rings were formed annually in the bastard grunt, we analyzed the monthly mean marginal increment (Hyndes and Potter, 1997). Marginal increment, estimated as the distance between the outer edge of the outermost annual ring and the periphery of each otolith, was measured (to the nearest 0.01 mm) with an ocular micrometer (Fig. 1). Measurements were always made along the longest axis of the otolith. The pattern expected in the marginal increment would be a minimal value at the start of the growth period, increasing with time until the measurement fell to a minimum again at the formation of the next period of growth (Pilling et al., 2000). The size of the marginal increment varies both with the age of the fish and the time of sampling during the year. Because older fish grow slower than younger fish, a smaller marginal increment is expected. For this reason, to assess the possibility of false annulus formation among either younger or older bastard grunt, quantitative marginal increment analyses should be standardized for age. Therefore, we used age class to standardize our analyses. Owing to the wide range of ages encountered, however, there were insufficient samples to fully accomplish this standardization. It was necessary to combine the ages in two or more age groups representing fast, moderate, and slow-growing individuals (Pilling et al., 2000). Mean marginal increments were plotted against month of capture, and the minimum was used to indicate the month of annulus formation.

Once the periodicity and timing of ring formation were verified, the age of each fish was determined from the number of annuli, the assumed birthdate, and the sampling date. It was assumed that annulus formation began 1 January, corresponding to the peak of spawning in the species (Gregoire[1]). The difference between the date of capture and the birthdate was used to estimate a fractional age (Gordoa and Molí, 1997). This fraction was added to the number of annuli read in the otoliths to avoid any potential bias in growth estimates due to differences in sampling date (Gordoa and Molí, 1997).

Length-at-age was described by the three-parameter specialized von Bertalanffy growth model (Ricker, 1973):

$$L_t = L_\infty(1 - e^{-k(t-t_0)}),$$

the four-parameter Schnute growth model (Schnute, 1981):

[1] Gregoire, M. 2001. Edad y crecimiento del roncador *Pomadasys incisus* (Bowdich, 1825) de Gran Canaria (Islas Canarias). Unpubl. data. ULPGC Socrates/Erasmus Research Report, 34 p. Departament of Biology, University of Las Palmas de Gran Canaria. 35017 Las Palmas de Gran Canaria. Spain.

$$L_t = \left[y_1^b + (y_2^b - y_1^b)\left(\frac{1-e^{a(t-A_1)}}{1-e^{-a(A_2-A_1)}} \right) \right]^{\frac{1}{b}},$$

and the seasonalized von Bertalanffy growth model (Pitcher and Macdonald, 1973)

$$L_t = L_\infty \left(1 - e^{-k(t-t_0)-\left(\frac{Ck}{2\pi}\sin\left(2\pi(t-t_s)\right)\right)} \right),$$

where A_1 = the smallest age in the sample;
A_2 = the largest age in the sample;
T_0 = the age at zero length;
L_t = the length-at-age;
L_∞ = the predicted asymptotic length;
y_1 = the estimated mean length of A_1-year-old fish;
y_2 = the estimated mean length of A_2-year-old fish;
C = the amplitude of the fluctuation in seasonal growth;
t_s = the point of the minumum growth (t_s=WP+ 0.5); and
k = the Brody growth constant (Schnute, 1981; Sparre and Venema, 1995).

The models were fitted to data with the Marquardt's algorithm for nonlinear least squares parameter estimation (Gayanilo et al*.,* 1996). A nonparametric, one-sample test was applied to test for residual randomness and a Bartlett's test was used to test for their homoscedasticity. Von Bertalanffy growth model parameters were also estimated for observed W_t as a function of age by substituting weights in place of lengths in the growth equation and incorporating b derived by the weight-length regression (Sparre and Venema, 1995):

$$W_t = W_\infty (1 - e^{-k(t-t_0)})^b,$$

where W_t = the weight at age; and
W_∞ = the predicted asymptotic weight.

Backcalculated size of each fish at the time of formation of each annulus was determined by a backcalculation formula consistent with the body proportional hypothesis (Campana, 1990; Francis, 1990). The measurements were the following: the radius of the i^{th} band (*Ri,* 0.01 mm, distance from the center of the otolith to the outer margin of the annulus) and the radius of the otolith at capture (*Rc*, 0.01 mm, distance from the center of the otolith to the periphery). These measurements were always made along the longest axis of the otolith (Fig. 1). The relationship between the radius of the otolith at capture (*Rc*) and the total length was estimated as a power function (nonlinear relationship). It is estimated by fitting the data by a regression of log(L_t) on log(*Rc*) consistent with the body proportional hypothesis (BPH). The length of an individual when the i^{th} band was laid down (*Li*, mm) was calculated as

$$Li = (Ri/Rc)^v Lc,$$

where Lc = the length-at-capture; and
v = a constant derived from the relationship of total length to otolith radius (Francis, 1990).

The von Bertalanffy growth curve was fitted to the backcalculated length-at-age by means of Marquardt's algorithm for nonlinear least squares parameter estimation (Gayanilo et al., 1996).

Results

Of the 878 fish examined, 377 (42.9%) were males and 412 (46.9%) females. The remaining 89 (10.1%) individuals were immature and could not be identified macroscopically. Fish varied in size from 103 to 304 mm L_t, and weighed between 8.7 and 137.1 g W_t. Males varied from 143 to 298 mm L_t, and total mass was from 9.3 to 114.7 g W_t. Female total length varied between 134 and 304 mm and total mass was from 13.2 to 137.1 g. Immature fish varied from 103 to 186 mm L_t and from 8.7 to 29.6 g W_t. No significant differences were found between males and females in mean size (Student's t-test, t=1.03<$t_{0.05,787}$=1.65) or weight (Student's t-test, t=1.57<$t_{0.05,787}$=1.65).

Sagittae of bastard grunt are ovate and laterally compressed. Annuli were clearly differentiated under reflected light on a black background: the opaque zones are milky in appearance and the hyaline zones relatively transparent (Fig. 1). The number of annuli counted for each individual were similar for the two readers. Of the 878 otoliths examined, 22 (2.5%) were rejected as unreadable, three were completely translucent, eight were broken, and 11 had poorly defined growth zones. Of the remaining 856 otoliths, consensus was reached for 812 (94.8%). The index of average percent error (IAPE) of band counts for each reader did not differ greatly, and was slighly lower for the first author (2.47) than for the second (2.69). The precision of the age estimates was also expressed as the CV as recommended by Campana (2001). The level of precision was approximately 5% for both readers.

Marginal increments were measured for 812 individuals. In the otoliths with one and two annuli (fast-growing young individuals), the lowest monthly mean marginal increments were recorded in January and increased throughout the year (Fig. 2). The marginal increments in the otoliths with three and more than three annuli (moderate and slow-growing individuals) also followed a similar trend. Thus, irrespective of the age of the fish, the marginal increments declined markedly and then rose progressively only once during a 12-month period. Therefore, only one annulus is formed in December–February.

Alternating opaque and hyaline zones were clearly visible on the otoliths. Up to seven marks, assumed to be annuli, were visible in the otoliths sampled. Two- and three-year-old fish were the dominant age classes and over 80% of fish were three years old or less (Table 1). Over 45% of the growth was achieved by the end of the first year. By the end of the second year, fish had attained 60% of the mean observed length.

The three growth models provided a good fit to the data (Table 2, Fig.3). Length-at-age was adequately described by the three models with the statistically suitable absolute error structure because it provided both residual randomness and homoscedasticity. The computed value of 0.15 for the winter point of the seasonalized von Bertalanffy growth model indicated that the lowest growth rate occurred at about two months after the birth date, meaning that the growth rate was reduced in winter.

No significant difference was found between the von Bertalanffy growth models with a likelihood ratio test (F=0.15<$F_{0.05;2;1560}$), and a significant difference was found between the von Bertalanffy growth models and the Schnute growth model with the same test (F>$F_{0.05;2;1560}$); therefore, the specialized von Bertalanffy growth model was chosen because it has fewer parameters making it statistically more robust, its parameters are commonly used in mortality estimates and per recruit modelling, and because it allows for comparison between growth studies conducted on other species (Booth, 1997). No significant differences were found between mean lengths-at-age of males and females with a Student's t-test (t=0.52<$t_{0.05,787}$=1.65) or between the von Bertalanffy growth curves for separate sexes with a Hotelling's T^2 test (T^2=4.73<${T_0}^2_{0.05,3,784}$=7.89). The data were pooled as a single growth model. In fitting the growth curve to the age-length data, age 0 was disregarded because this age group was not well represented. The von Bertalanffy growth curve derived from the observed weight at age for males and females was not significantly different (Hotelling's T^2-test, T^2=6.91<${T_0}^2_{0.05,3,784}$=7.89; Fig. 4).

Fish total length and otolith radius were closely correlated (Fig. 5). The value of the derived constant (v=0.851) was different from one (Student t-test; t=14.61 > $t_{0.05,810}$=1.65). Backcalculated size at time of annulus formation was used to provide length-at-age data unbiased by differences in sampling date and to estimate the von Bertalanffy equation (Table 3). Backcalculated lengths were similar to those predicted by the growth models. Growth parameters estimated from the backcalculated sizes at age were L_∞=315.23 mm; k=0.217/year; and t_0=–1.733 year. The data was pooled as a single growth model because no significant differences in the growth parameters were found between males and females (Hotelling's T^2-test, T^2=48.3>${T_0}^2_{0.05,3,784}$=7.89).

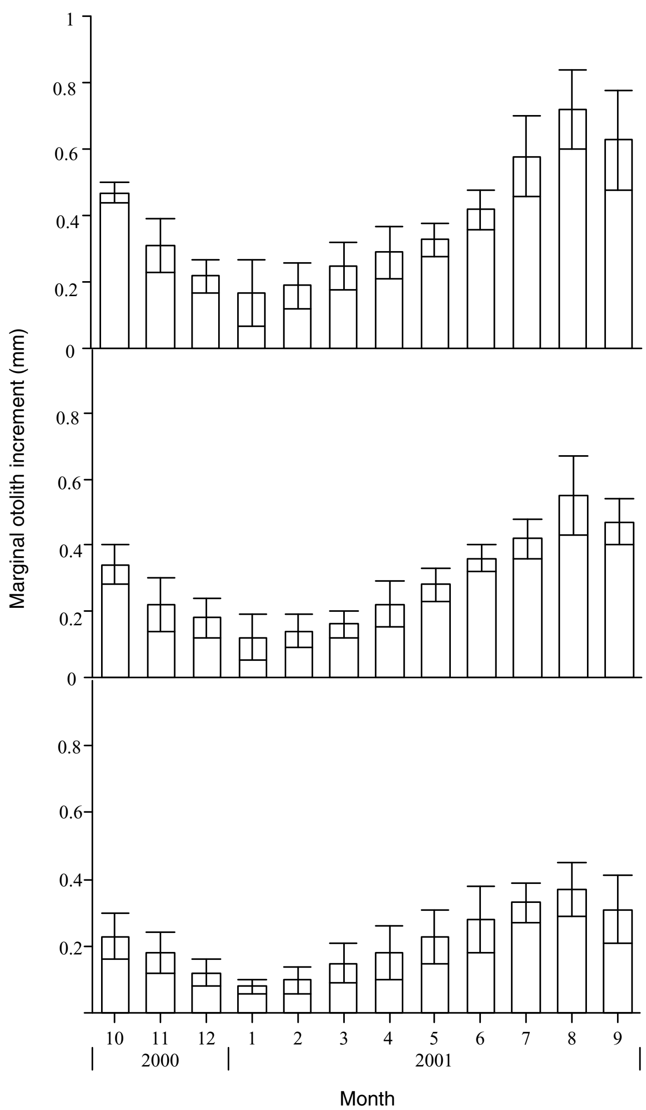

Figure 2

Mean monthly marginal increment from otoliths with one and two, three, and more than three annuli, representing fast, moderate, and slow-growing individuals of *P. incisus* off the Canary Islands. Standard errors are identified by the bars.

Discussion

Age estimation in fishes is complicated by the phenomenon of "stacking" of growth zones towards the otolith margin, particularly in older fish (Buxton and Clarke, 1991). In many cases age determination is difficult because whole otoliths are so thick that light does not pass through (Buxton and Clarke 1991); however, in the bastard grunt off the Canary Islands the translucency of the otoliths allows aging with relative ease. The values of the IAPE and the CV suggested that the precision levels obtained are according to the reference point values indicated by Campana (2001). The oldest age estimate obtained in the present study was seven years and the phenomenon of stacking was not evident.

The otoliths of the bastard grunt have a ring pattern common to teleost fishes. Marginal increment analysis demonstrated that one annulus, consisting of one opaque zone and one hyaline zone, is formed annually. These rings are believed to be deposited during periods of fast and slow growth, respectively (Williams and Bedford, 1974). Seasonal growth cycles might be related to physiological changes produced by the influence of temperature, feeding regime, and reproductive cycle (Morales-Nin and Ralston, 1990). The seasonalized von Bertalanffy growth model reveals the reduc-

Table 1

Sample size per age group (age-length key) and percentage (in parentheses) within each age group for all fish of *P. incisus* collected off the Canary Islands. *n* is the number fish by age class and SD is the standar deviation. Total length classes are given in 10-mm intervals.

	Age groups (year)							
Size (mm)	0	I	II	III	IV	V	VI	VII
100	2 (40.0)	3 (60.0)						
110	1 (8.1)	10 (90.9)						
120	1 (5.6)	17 (94.4)						
130		19 (100.0)						
140		15 (71.4)	6 (28.6)					
150		4 (17.4)	19 (82.6)					
160			33 (100.0)					
170			47 (95.9)	2 (4.1)				
180			69 (70.4)	29 (29.6)				
190			52 (46.6)	61 (53.4)				
200			25 (20.5)	96 (78.6)	1 (0.9)			
210			14 (12.8)	89 (81.6)	6 (5.5)			
220			5 (5.9)	57 (67.0)	23 (27.1)			
230				14 (27.0)	38 (73.0)			
240				2 (10.0)	17 (85.0)	1 (5)		
250				1 (6.6)	9 (60.0)	4 (26.8)	1 (6.6)	
260					2 (20.0)	6 (60.0)	2 (20.0)	
270					1 (25.0)	1 (25.0)	2 (50.0)	
280						1 (33.3)	1 (33.3)	1 (33.3)
290							1 (100)	
300								1 (100.0)
Mean	107	125	176	212	236	261	275	295
n	4	68	270	351	97	13	7	2
SD	5.77	12.64	17.28	18.06	12.36	11.43	11.40	14.14

Table 2

Parameters estimates, standard errors, and 95% cofidence intervals for the specialized von Bertalanffy, Schnute, and seasonalized von Bertalanffy growth models for all *P. incisus* collected off the Canary Islands. All models were pooled without the age-0 class.

			95% confidence intervals	
Parameter	Estimate	Standard error	Lower	Upper
Specialized von Bertalanffy growth model (r^2=0.91)				
L_∞ (mm)	309.58	8.06	294.07	325.08
k (/year)	0.220	0.031	0.157	0.283
t_0 (year)	–1.865	0.055	–2.007	–1.723
Schnute growth model (r^2=0.87)				
y_1 (mm)	126.66	1.51	124.54	128.78
y_2 (mm)	293.50	9.50	286.68	300.32
A	–0.426	0.077	–0.578	–0.274
B	5.963	0.664	4.659	7.267
Seasonalized von Bertalanffy growth model (r^2=0.91)				
L_∞ (mm)	309.93	7.68	295.21	324.65
K (/year)	0.218	0.032	0.153	0.282
t_0(year)	–1.896	0.049	–2.067	–1.725
C	0.555	0.212	0.138	0.971
t_s	0.652	0.061	0.532	0.773

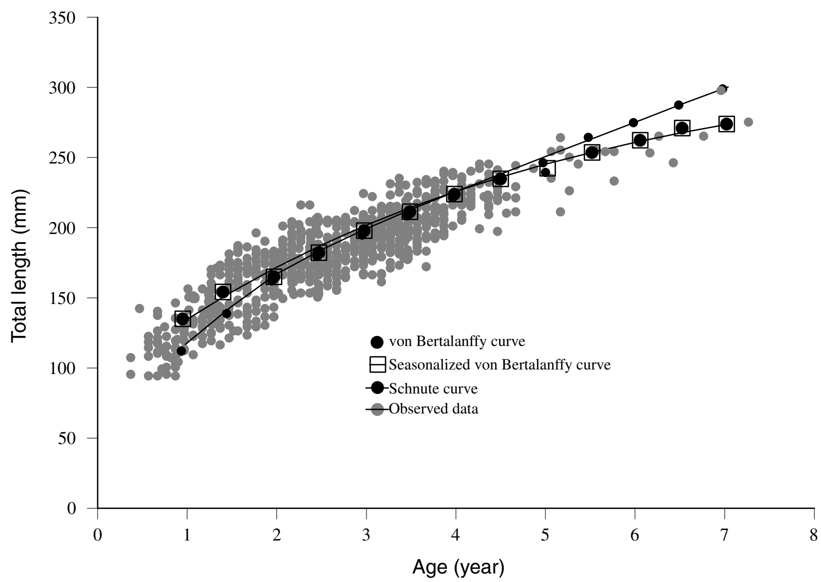

Figure 3

Von Bertalanffy specialized and seasonalized growth curves and the Schnute growth curve for all individuals of *P. incisus* collected off the Canary Islands.

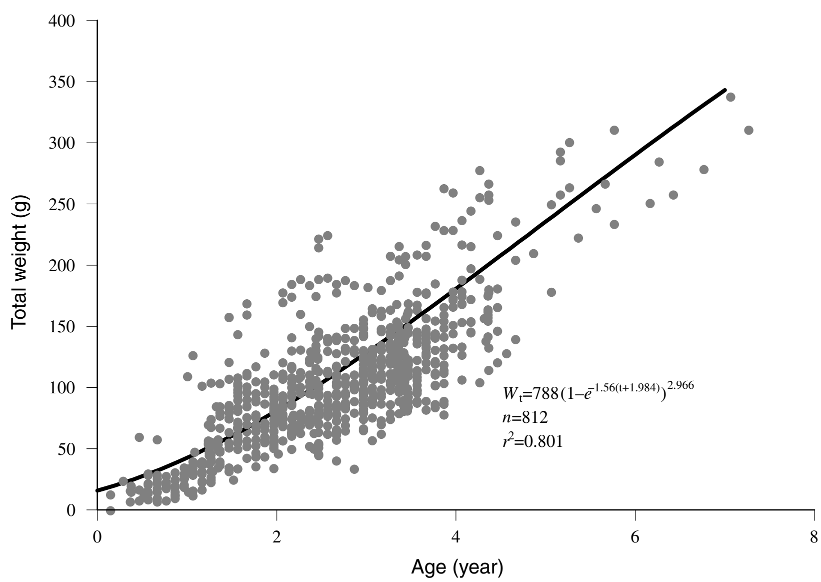

Figure 4

Von Bertalanffy growth curve derived from observed weight at age for all *P. incisus* collected off the Canary Islands.

tion of somatic growth and the formation of the hyaline zone during the winter months. The high correlation found between L_t and otolith radius indicates that otoliths are a useful structure for estimating the age and for indicating the past growth history of bastard grunt.

The coefficients of determination for each fitted curve show that the three models explain more than 88% of the growth pattern. The use of the von Bertalanffy model to describe growth has been criticized for several reasons (Booth, 1997). These include the use of parameters that

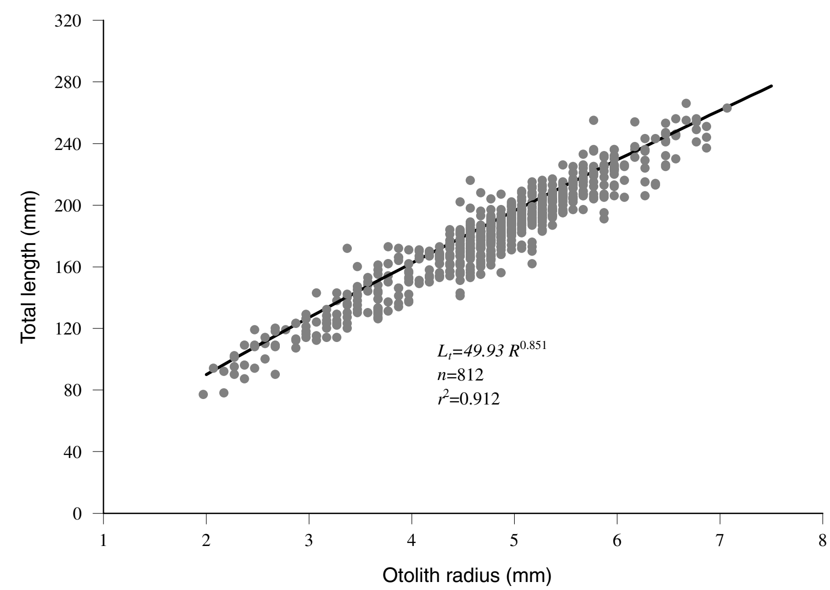

Figure 5

The relation of otolith length to total length for *P. incisus* collected off the Canary Islands.

Table 3

Backcalculated length-at-age for all *P. incisus* collected off the Canary Islands.

Age (year)	Number of fish	Annulus number I	II	III	IV	V	VI	VII
1	68	119						
2	270	123	179					
3	351	127	172	219				
4	97	132	168	212	235			
5	13	129	178	205	245	26		
6	7	122	170	221	233	257	275	
7	2	128	174	214	239	260	279	293
Mean		126	173	214	238	259	277	293
Number of backcalculated lengths at age		808	740	470	119	22	9	2
Annual growth increment (mm)		126	47	41	24	21	18	16
Annual growth increment (%)		43.0	16.1	13.9	8.2	7.2	6.1	5.4

have little biological meaning (Schnute, 1981) and the absence of parameters that take into account seasonal changes in growth rate (Pauly, 1980; Moreau, 1987). Nevertheless, the von Bertalanffy growth model has been used extensively to describe the growth of grunts. The growth model provides a simple description of growth which can be compared between species and species groups (Booth, 1997). The special and the seasonal forms of the von Bertalanffy growth model were chosen for the present study because they contain fewer parameters than the Schnute growth model.

Backcalculated lengths-at-age are in close agreement with the length estimated from otoliths readings. The results obtained with the backcalculation method are very satisfactory because they show the consistency in the interpretation of the sequence of growth increments of the bastard grunt off the Canary Islands and reduce the effect of size-selective sampling bias on the length estimates for youngest fish in the sample (Campana, 2001).

The growth parameters obtained are reasonable because the theoretical maximal length value is higher than the size of the largest fish sampled and the growth coefficient

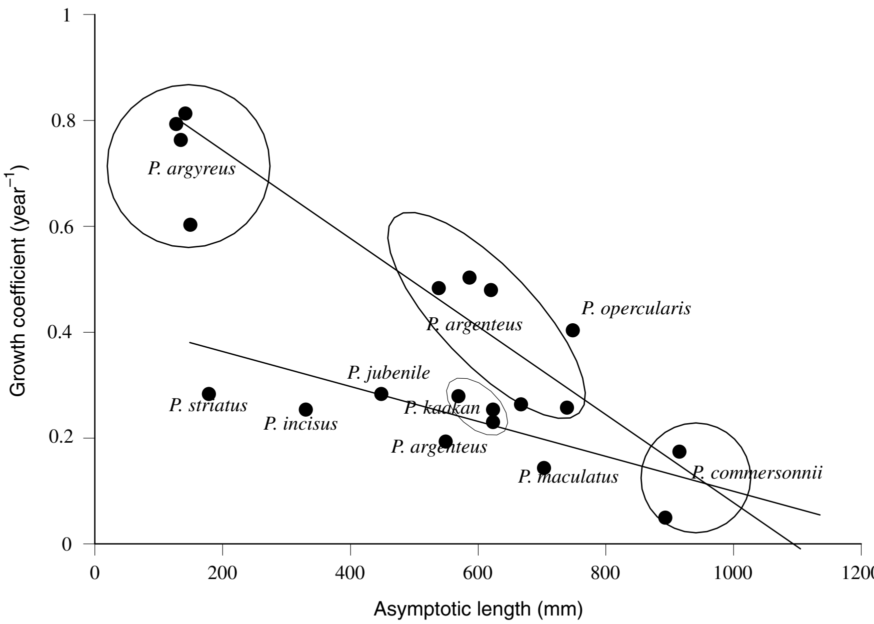

Figure 6

The relation of asymptotic length to the growth coefficient for different species of the *Pomadasys* genus.

value indicates a relatively fast attainment of maximum size, characteristic of the moderately short life cycle for this species. However, the estimations of t_0 tend to be negative and different from zero for values affected by the small sample size of smaller fish. These estimations suggest that the von Bertalanffy growth model does not accurately describe growth in the early stages. *Pomadasys incisus* grows quickly in its first year, attaining approximately 60% of its maximum length. After the first year, the annual growth rate drops rapidly. This change in growth rate is attributable to the utilization of available energy for reproduction instead of somatic growth; in the study area the maturation process begins in the second year of life (Gregoire[1]).

Two different patterns of growth rate in relation to asymptotic length are observed for *Pomadasys* species (Fig. 6). The pattern of *P. incisus* is similar to that observed for *P. striatus, P. jubeline*, *P. kaakan*, *P. maculates,* and *P. commersonnii*—species characterized by a high or moderate asymptotic length and low or moderate growth coefficient (Latif and Shenouda, 1972; Wallace and Schleyer, 1979; Edwards et al., 1985; Iqbal, 1989; Al-Husaini et al., 2001; Pauly[2]). However, it differs substantially from that observed for *P. argyreus*, a species with a very low asymptotic length (<151 mm) and a very high growth coefficient (0.62–0.83/year), and for *P. opercularis* and *P. argenteus,* species characterized by a high asymptotic length and a high growth coefficient (550–741 mm; 0.28–0.52/years) (Deshmukh, 1973; Nzioka, 1982; Brothers and Mathews, 1987; Majid and Imad, 1991; Ingles and Pauly[3]).

Results of models used in fisheries management, e.g. analytical yield-per-recruit models (Beverton and Holt, 1957), are sensitive to uncertainty in the estimates of input parameters such as the von Bertalanffy growth parameters. Several estimations of growth in *Pomadasys* species have been derived through length-based methods, which for slow growing species are uncertain. The growth parameters from this study are the first otoliths-based estimates of growth for *P. incisus*. Similar estimates obtained from different growth models and methods suggest that the current estimation could be considered a good estimation of the growth pattern for the species and adequate for use as an input parameter in models for the management of the species.

Acknowledgments

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