



Age and growth in the Alfonsino, *Beryx splendens* (Berycidae) from the Azores (central eastern Atlantic)

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ABSTRACT

Age was determined in the Alfonsino, *Beryx splendens*, by counting the opaque rings on the anti-sulcal surface of left sagittae obtained from specimens, 15-43.5 cm fork length (FL), caught off the Azores. Females were from 1 to 12 years old and males were 1 to 9 years old. Von Bertalanffy (VB) growth equations were fitted to data obtained from age-length keys, back calculation, and length-frequency analyses. Growth was compared between sexes and among methods. Growth was similar in males, whereas in females the equations derived from length-frequency analysis overestimated length-at-age relative to other methods. Sex specific growth could not be confirmed.

KEY WORDS: Berycidae - *Beryx splendens* - Azores - Age - Growth - Otoliths.

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INTRODUCTION

The Alfonsino, *Beryx splendens* Lowe, 1834, is a demersal fish species that inhabits the continental slope (200-600 m depth) in the eastern Atlantic (Quéro, 1984) and seamounts around the islands of Madeira, the Canaries and the Azores (Maul, 1986). This species can also be found in the western Atlantic, Pacific and Indian Oceans (Bushakin, 1982 in Kotlyar, 1987). It is a by-catch of the *Pagellus bogaraveo* artisanal fishery in the Azores. The landings increased from 3 metric tons in 1980 (< 1% of the fishery landings) to 635 metric tons in 1994 (> 67%) (Lotaçor, 1980-1995). Available information on age and growth of Alfonsino from the Atlantic has come from fisheries sources and consists mainly of length-frequency, catch curves, age frequencies and length-at-age curves (León & Malkov, 1979; Kotlyar, 1987; ICES, unpublished report; Assessment Committee, 1995-1996; Gauldie, 1995). The objectives of this study were to determine the age from *sagittae* otoliths and to conduct a preliminary growth study of the Alfonsino from the Azores.

MATERIALS AND METHODS

A total of 406 specimens were caught at stations off the Azores archipelago using bottom long line on board the R/V 'Arquipélago' in March and April 1995. Each fish was measured for fork length (FL) to the nearest cm with a calliper; sex was determined macroscopically; otoliths (*sagittae*) were extracted, cleaned and stored dry. Whole left *sagittae* ($n = 404$, 180 males and 224 females) were examined in 96% ethanol, under a compound stereoscope with reflected light over a dark background. Opaque rings were counted on the anti-sulcal otolith surface. Whenever interpretation of the otoliths was questionable the otoliths were discarded. A sub-sample of 95 *sagittae* previously read, was chosen for ring measurement. The individuals for the sub-sample were selected according to assigned age, fish length and sex; 50 males and 45 females. The distance from the *focus* to the distal edge of the otolith (otolith radius, OR) and to the outer margin of each opaque ring (ring n radius, OR_n) was measured. Length-frequency analysis (LFA) was performed using the Bhattacharya and Hasselblad methods implemented in the FiSAT software package (Gayanilo *et al.*, 1994). The goodness-of-fit of composite distributions was derived from Separation Index (SI) values and tested using Chi-square tests. The relationships between FL and OR, and between OR and ring counts (RC) were examined by regression analyses and the significance of the regressions values was tested. Intercept and slope parameters were compared between sexes using Students t -test. Lengths (FL, cm) at age for individual fish were back-calculated according to Francis (1990). Von Bertalanffy growth equations (Bagenal & Tesch, 1978) were fit to mean length-at-age data sets derived from age-length keys (ALK), back calculation analysis (BL), and LFA, using the FiSAT automated procedures (see details in Gayanilo *et al.*, 1994). Best fits, i.e. the equations maximising the Phi-prime test value (see Sparre & Venema, 1992) and r^2 , and the more biologically meaningful parameters were chosen for analysis.

RESULTS AND DISCUSSION

Female, 15.0-43.5 cm FL, were assigned to ages from 1 to 12 years, while males, 15-36 cm FL, were estimated

to be 1 to 9 years old. Seven components were identified in the length-frequency distribution of both males and females (Table I). The separation index (SI) values were greater than 2.0, except for component no. 5 in the male length-frequency distribution (SI = 1.93). The composite distributions for males and females were not significantly different from the observed values ($\chi^2 = 4.13$ and $\chi^2 = 20.8$, $P > 0.05$, respectively). The relationships between OR/RC and FL were best and significantly ($P < 0.001$) described by positive, linear equations. Intercepts and slopes were not different between sexes ($P > 0.05$) (Table II). Mean back-calculated lengths at age were from 15.5 cm to 39.0 cm FL in females and from 17.5 cm to 34.8 cm FL in males. VB equations obtained from direct otolith age determination are as follows:

$$L = 45.3 \cdot 1 - \exp[-0.133 \cdot (t + 2.74)] \text{ females}$$

$$L = 53.7 \cdot 1 - \exp[-0.085 \cdot (t + 4.02)] \text{ males}$$

$$L = 46.1 \cdot 1 - \exp[-0.120 \cdot (t + 3.18)] \text{ sexes combined.}$$

Male growth (as indicated by the VB equations) was similar irrespective of the model upon which they were based, whereas female growth derived from LFA overestimated mean FL at age relative to ALK- and BL-based models. Within the age span studied, lengths estimated by BL-based equations were generally shorter than those predicted by ALK- and LFA-based models (Fig. 1).

Age determination in Alfonsino is still an open issue. Although basic criteria have been established, only Russian researchers seem to have standardised preparation procedures (see Kotlyar, 1987). Problems associated with age determination of Alfonsino using otoliths have been summarized by Gauldie (1995). The complexity of the opaque banding structure of *Beryx splendens* otoliths results in an increased number of zones or bands with increasing magnification. The otolith nucleus can be regarded as the first broad opaque zone, even though there are evidently minor opaque zones within this region (Gauldie, 1995). Therefore, in the present study, that region was considered to be the first

TABLE I - Modes identified in the female (F) and male (M) length-frequency distributions, using Bhattacharya's or Hasselblad's method. N', calculated number of individuals, FL, fork length (cm), SD, standard deviation, SI, separation index, and 1.96 - slightly non-significant.

Component	N'		Mean FL		SD		SI	
	F	M	F	M	F	M	F	M
1	22	1	19.6	15.5	1.00	0.16	-	-
2	26	8	22.9	19.2	0.88	0.92	3.55	6.81
3	67	43	26.2	23.1	1.21	1.13	3.09	3.79
4	39	24	29.6	25.5	0.79	0.26	3.39	3.51
5	24	81	33.3	27.9	0.95	2.26	4.31	1.96
6	12	8	36.6	32.5	0.71	0.33	3.95	3.54
7	7	15	39.1	35.1	0.93	0.86	3.02	4.41

TABLE II - Linear regression parameters calculated for the relationships between otolith radius (OR), fork length (FL), and ring counts (RC) in Alfonsino from the Azores.

Relationship	a (\pm SE)	b (\pm SE)	r ²
OR:FL			
Female	-13.44 (3.803)	7.44 (0.676)	0.738
Male	-6.62 (3.904)	6.14 (0.711)	0.777
Pooled sexes	-10.28 (2.712)	6.84 (0.488)	0.679
OR:RC			
Female	4.63 (0.124)	0.213 (0.023)	0.663
Male	4.54 (0.138)	0.253 (0.053)	0.558
Pooled sexes	4.61 (0.089)	0.225 (0.019)	0.605

a, intercept; b, slope; SE, standard error; r², coefficient of determination. All equations highly significant ($P < 0.001$).

annulus. An annual rhythm of increment deposition in the Alfonsino otoliths has not yet been validated, but a study by Kotlyar (1987) came to a similar conclusion regarding annulus formation. Oppositely, Gauldie (1995) stated that the zones observed are caused by surface sculpturing and he found no direct evidence to support an interpretation that they are deposited annually. In spite of these contradictory results, herein the rings were assumed to be deposited annually. According to Gauldie (1995) direct observation of zones/checks/bands/rings/micro-increments have produced conflicting age estimates. Nonetheless, Kotlyar (1987) found 100% agreement in age estimates from otoliths and scales. In the present study, the age span as estimated from direct observation of otoliths were different from those obtained from LFA. According to Sparre & Venema (1992) it is often difficult to obtain an unambiguous interpretation of a length-frequency data set, particularly when there is only a single, complex length-frequency sample available and no time series information relative to length.

The significance of the regression line fit to the FL:OR and RC:OR data reinforced the use of otoliths for age determination in Alfonsino. León & Malkov (1979) and Gauldie (1995) also found significantly linear relationships between fish length and otolith radius (pooled sexes). Similar regression parameters between sexes indicates similar growth patterns in males and females. Back-calculated lengths at age are generally shorter than the observed FL, which is, at least partially, the result of the occurrence of some growth between the time of annulus formation and capture.

Despite the differences found in female VB growth, presumably related to the difficulties in the analysis of length-frequency distributions, sex specific growth could not be confirmed. Similarly, Kotlyar (1987) analysed data for each sex and was not able to distinguish growth differences between males and females. The growth

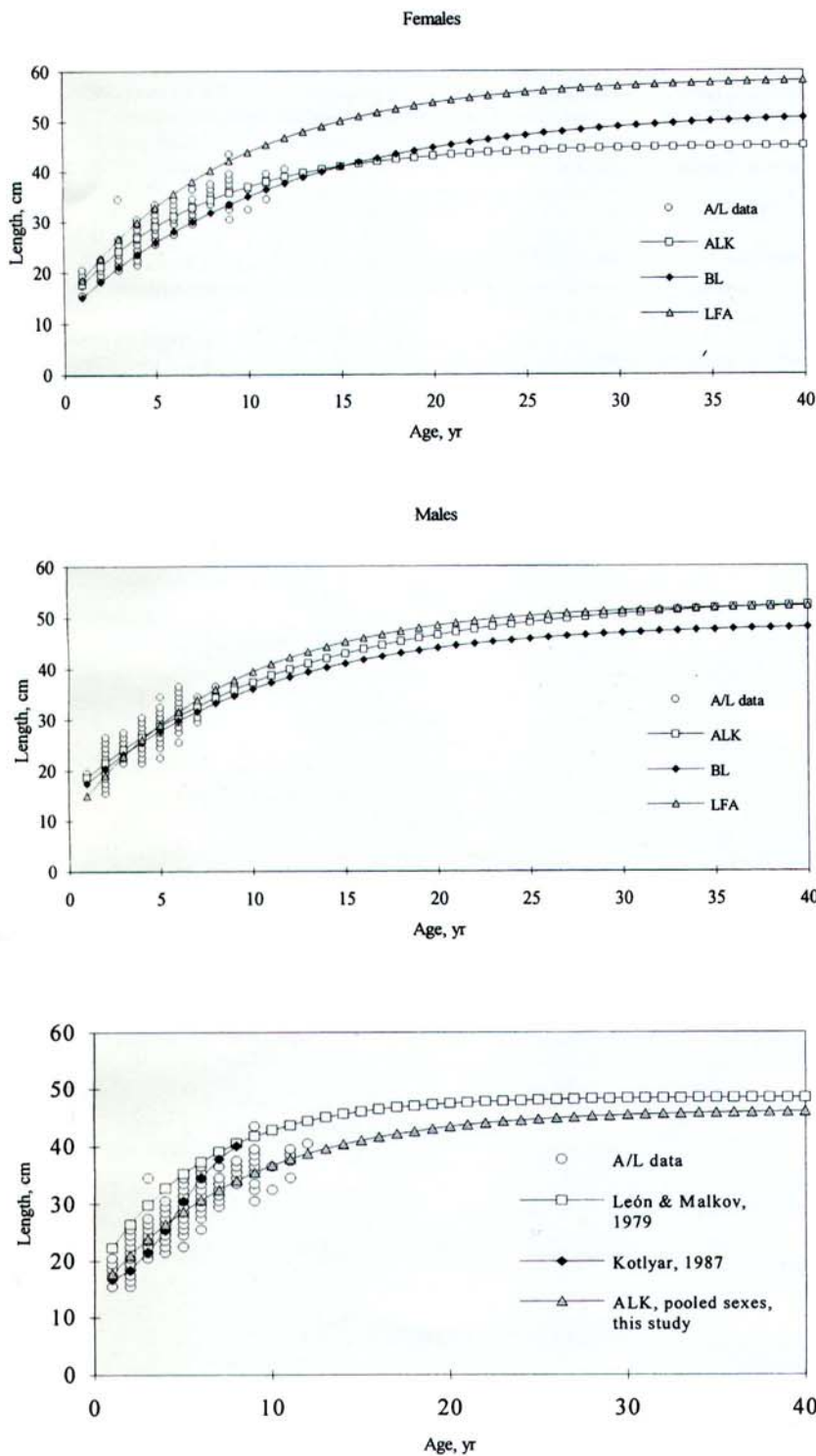


Fig. 1 - VB growth curves calculated for Alfonsino from the Azores using age-length keys (ALK), back-calculation analysis (BL) and length-frequency analysis (LFA). Original age-length data (A/L data) is also included.

Fig. 2 - Comparison of ALK-based VB growth curves obtained in this study and those published in the literature for the Atlantic. ALK, age-length key; A/L data, original age-length data.

rate is higher during the first year of life, about 18-19 cm, but decreases thereafter. Likewise, Kotlyar (1987) and ICES (unpublished report: Assessment Committee, 1995) indicated that Alfonsino can grow up to 16-17 cm in the first year, decreasing to about 2-5 cm by the 7-9th year of age. In this study, the VB-predicted lengths-at-age (ALK) were slightly lower than the values referred to for the western central (León & Malkov, 1995) indicated

t and south eastern Atlantic (Kotlyar, 1987) (Fig. 2). Segregation by age and sex has been described by Lehodey *et al.* (1994) for Alfonsino from New Caledonian seamounts. Behavioural segregation might explain the differences between sexes obtained in the present study, and between our results and those reported for the region (León & Malkov, 1979; Kotlyar, 1987; ICES, unpublished report: Assessment Committee, 1995).

REFERENCES

- Bagenal T. B., Tesch F. W., 1978 - Age and growth. *In*: T. B. Bagenal (ed.), Methods for the assessment for the fish production in freshwater. Blackwell Scientific Publications, Oxford, pp. 101-136.
- Francis R. I. C. C., 1990 - Back-calculation of fish length: a critical review. *J. Fish Biol.*, 36: 883-902.
- Gayanilo F. C., Sparre P., Pauly D., 1994 - FISAT. The FAO-ICLARM Stock Assessment Tools User's Guide. Food and Agriculture Organization of the United Nations, Rome, 157 pp.
- Gauldie R. W., 1995 - Biological history and estimation from the zones, checks and microincrements of the otolith of the alfonsino, *Beryx splendens* (Berycidae). *Cybium*, 19: 107-129.
- Kotlyar A. N., 1987 - Age and growth of alfonsino, *Beryx splendens*. *J. Ichthyol.*, 27: 104-111.
- Lehodey P., Marchal P., Grandperrin R., 1994 - Modelling the distribution of Alfonsino, *Beryx splendens*, over the seamounts of New Caledonia. *Fish. Bull.*, 92: 748-759.
- Léon, M. E., Malkov A., 1979 - Estudio preliminar de la edad y crecimiento del *Beryx splendens*, Lowe del Atlántico centro-Occidental. *Rev. Cub. Investig. Pesq.*, 4: 62-73
- Lotaçor, 1980/1995 - O pescado descarregado nos Portos da Região Autónoma dos Açores. Elementos estatísticos do Serviço Açoreano de Lotas E. P. - Lotaçor. Anuários relativos aos anos de 1980 A 1995, Horta, 359 pp.
- Maul G. E., 1986 - Berycidae. *In*: P. J. P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen & E. Tortonese (eds), Fishes of the North-eastern Atlantic and Mediterranean - vol. III. UNESCO, Bungay, pp. 740-742.
- Quéro J. C., 1984 - Les poissons de mer des pêches françaises. Maquette Dominique et Philippe Lemmonier, Paris, 394 pp.
- Sparre P., Venema S. C., 1992 - Introduction to tropical fish stock assessment: Part I - Manual. *FAO Fish. Tech. Pap.*, 306, 376 pp.