

Age and growth of the alfonsino *Beryx decadactylus* (Cuvier, 1829) from the Azores, Madeira and Canary Islands, based on historical data

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Age and growth of the alfonsino *Beryx decadactylus* from the Azores, Madeira and Canary Islands were studied based on otolith readings. Alfonsino otoliths are thin and show clear annual growth rings. Specimens ranged in size from 21.0 to 50.0 cm fork length (aged 2 to 10 years) in the Azores, 20.0 to 45.0 cm fork length (1 to 11 years) in Madeira, and 21.0 to 44.0 cm fork length (0 to 9 years) in the Canary Islands. No significant differences in growth parameters were found between males and females in any of the three archipelagos. The von Bertalanffy growth parameters for all individuals were: $L_{\infty}=68.40$ cm L_F , $k=0.11$ year⁻¹, $t_0=-1.90$ year in the Azores; $L_{\infty}=70.10$ cm L_F , $k=0.07$ year⁻¹, $t_0=-4.83$ year in Madeira; $L_{\infty}=58.11$ cm L_F , $k=0.11$ year⁻¹, $t_0=-4.70$ year in the Canary Islands. No significant differences in growth parameters were found between the three archipelagos.

Key words: Berycidae, comparative growth analysis, Macaronesian archipelagos, longevity, growth overfishing

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INTRODUCTION

The alfonsino *Beryx decadactylus* has a worldwide distribution, occurring throughout the Atlantic, Pacific and Indian Oceans, and western Mediterranean, in tropical, subtropical and some temperate areas (Maul 1981; Maul 1986; Maul 1990; Busakhin 1982). In the north-eastern Atlantic, *B. decadactylus* is common in Spanish and Portuguese waters, including the Azores, Madeira and Canary Islands (Albuquerque 1956; Maul 1981; Maul 1986; Maul 1990).

Beryx decadactylus is a benthopelagic species found on rocky bottoms. This species normally lives near the bottom of the upper slope between 200 and 900 m depth, most commonly between 400 and 600 m (Maul 1981; Maul 1986).

In the Azores, *B. decadactylus* is one of the target species of a traditional demersal fishery with handlines and longlines that operates off the coasts of the islands and at various seamounts in the Azorean EEZ down to 900 m. In Madeira, *B. decadactylus* is a bycatch species in the handline and longline demersal artisanal fishery between 250 and 750 m depth. In the Canary Islands, *B. decadactylus* is a secondary species in the small-scale demersal fishery for *B. splendens* off Gran Canaria and El Hierro islands with handlines and bottom drop lines at about 400-700 m depth.

The alfonsino, and its congener, the splendid alfonsino (*B. splendens*) are both common in the three archipelagos and in the same fisheries. A similar study has been undertaken for *B. splendens* (Rico et al. 2001), but despite the growing

interest in these species, information available on the biology of *B. decadactylus* continues to be scarce worldwide. Studies are mainly limited to ontogenic development (e.g. Mundy 1990), age, growth and reproduction in the Azores (e.g. Isidro 1996; Krug et al. 1998; Estácio et al. 2001), and feeding habits in the Azores and Canary Islands (e.g. Gomes et al. 1998; Durr & González 2002).

The objective of this paper was to present data on the age and growth of *B. decadactylus* off the Azores, Madeira and Canary Islands. This information, while providing insight into the life history patterns of the species, is essential for adequate stock assessment and management of the fishery in the Macaronesian archipelagos.

MATERIAL AND METHODS

Specimens of *B. decadactylus* were collected by a random length-stratified method from catches onboard commercial and research vessels in the Azores, Madeira and Canary Islands between March 1995 and December 1997. For each fish, the fork length (L_F) was measured to the nearest millimetre below. A total of 405 individuals were sampled in the Azores (ranging between 21.0–50.0 cm L_F), 143 individuals in Madeira (between 20.0–45.0 cm L_F), and 111 individuals in the Canaries (between 21.0–44.0 cm L_F).

Sex was determined macroscopically, and sagittal otoliths were removed, cleaned, dried, and stored in labelled plastic vials or paper envelopes. Age was determined by interpreting growth rings on the otoliths. Whole otoliths (both pair of *sagittae* for each specimen) were placed in a watch glass with blackened-bottom containing water and viewed distal surface up under a compound microscope (18x) with reflected light. Age was assessed from counts of opaque rings; a hyaline and an opaque zone were assumed to represent one year's growth. January 1st was considered as the birth date to assign individual ages to age groups.

In order to assess accuracy between readers, each region received a sub-sample of 30 pairs of otoliths from the other two archipelagos. Readings were undertaken twice and only coincident interpretations were accepted. The von Berta-

lanffy growth equation was fitted to the resulting age-length key data by means of the Marquardt's algorithm for non-linear least squares parameter estimation (Saila et al. 1988). The form of the growth equation used was taken from Beverton & Holt (1993), as follows:

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

Where: L_{Ft} is the fish fork length at age t ; L_{∞} the asymptotic fork length; k the VB growth coefficient; and t_0 the hypothetical age when fish length is zero.

Since the parameter estimates of the von Bertalanffy growth function are difficult to compare statistically (Roff 1980), relationships between length and age were also modelled in a linear form after logarithmic transformation of the age variable as:

$$L_{Fi} = a + b \ln(t)$$

Variations by sex and between regions were compared by testing for differences in mean length using \ln age as the covariate (Mayo et al. 1990). The covariance analysis (ANCOVA) was performed using a statistical software package: StatisticaTM v/6.0 for Windows XP.

The growth performance index ($\Phi' = 2\log L_{\infty} + \log k$, Munro & Pauly 1983) was estimated for comparison between the three regions and with those reported by other authors.

RESULTS

Otoliths of *B. decadactylus* were found to be thin and, in general, showed clear annual growth rings with translucent zones appearing as dark bands and opaque zones as white bands. Both zones were concentric to the outer edge of the otolith and best visible on the anterior part of the otolith.

By assuming that otolith zones are formed annually throughout the entire lifespan of the individual, the number of annuli counted was converted into ages. Covariance analysis indicated no significant differences (ANCOVA, $P > 0.05$) in the regression coefficients of the length vs. \ln age model between males and females in the three regions and, as a result, both sexes were combined in the analysis.

Of the 405 otoliths examined from the Azores, 395 (97.5%) were readable and used for the age and growth study. Age estimates ranged from 2 to 10 years (Table 1), and the von Bertalanffy growth parameters determined for the Azores sample were: L_{∞} =68.40 cm L_F , k =0.11 year⁻¹, and t_0 =-1.90 year (Fig. 1). From Madeira, 137 otoliths, (95.8%) were readable with ages ranging from 1 to 11 years (Table 2). The von Bertalanffy growth parameters estimated for the Madeira

specimens were: L_{∞} =70.10 cm L_F , k =0.07 year⁻¹, and t_0 =-4.83 year (Fig. 1). From the Canary Islands, 105 of the 111 examined otoliths (94.6%) were readable and used in the age and growth analysis. Fish between 0 and 9 years were present in this sample (Table 3). The von Bertalanffy growth parameters obtained for all specimens from the Canary Islands were estimated as: L_{∞} =58.11 cm L_F , k =0.11 year⁻¹, and t_0 =-4.70 year (Fig. 1).

Table 1. Age-length key for *B. decadactylus* from the Azores based on all examined individuals.

Size class (L_F cm)	O	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
20												0
21			2									2
22			9									9
23			9									9
24			6	3								9
25			3	13	1							17
26			7	8	1							16
27			2	14	12							28
28				6	7							13
29				2	5							7
30				2	15	1						18
31				2	10	3						15
32				2	8	9						19
33					4	11	2					17
34					8	4						12
35					3	4	6					13
36					1	3	11					15
37						4	17	1				22
38					1	6	6					13
39					1	7	8					16
40						8	6	10				24
41						3	2	17				22
42					1	2	2	1	10			16
43						1	4		6			11
44							5	1	8			14
45							4	2	1	5		12
46							1	4		6		11
47						1				5		6
48									2	2	1	5
49											2	2
50											1	1
51									1			1
N	0	0	38	52	78	67	74	36	28	18	4	395
x			24.2	27.3	31.2	36.7	39.2	42.0	44.1	46.7	49.5	
sd			1.7	2.0	2.8	3.5	3.2	2.1	2.1	1.0	0.8	

Table 2. Age-length key for *B. decadactylus* from Madeira based on all examined individuals.

Size class (L_F cm)	Age group (year)											Total	
O	I	II	III	IV	V	VI	VII	VIII	IX	X	XI		
20	1											1	
21												0	
22	2											2	
23	3											3	
24	3	3										6	
25	2	2	1									5	
26	2	7	1									10	
27		3	6	3	2							14	
28			5	4								9	
29		1	1	2	1							5	
30			3	2								5	
31		1	1	5	1							8	
32				1	2							3	
33				5		1						6	
34			1	4	1	3						9	
35					2	1						3	
36				1	1	1	4					7	
37						1	2					3	
38						1	1	1				3	
39					1	3	1	2				7	
40					3	1	1	1				6	
41						1	2	2	1	1		7	
42					1	1	1		1			4	
43						1	2	1	1			5	
44								1				1	
45						1			1	1	1	4	
46												0	
47												0	
48												0	
49												0	
50												0	
51								1				1	
N	0	13	17	19	27	15	16	14	9	4	2	1	137
x		24.1	26.7	28.8	31.5	35.1	38.6	39.4	41.1	43.2	43.2	45.5	
sd		1.7	1.8	2.0	2.6	4.9	3.6	2.7	2.1	1.7	2.8		

The growth curves obtained for the three regions were compared through a covariance analysis (ANCOVA) performed on the slopes obtained from the length vs. ln age regressions. Results showed that the curves were not significantly different for a $F_{(2,32)} = 2.97$; $P = 0.0658$.

A Newman-Keuls test was applied to compare

the L paired means (Table 4), and results indicated no significant differences between the three regions. Table 5 presents the values of the growth performance index (Φ') estimated for *B. decadactylus* in several different geographical areas where growth parameters have been previously estimated.

Table 3. Age-length key for *B. decadactylus* from the Canary Islands based on all examined individuals.

Size class (L _F cm)	Age group (year)									Total	
	O	I	II	III	IV	V	VI	VII	VIII		IX
20											0
21	2										2
22	3										3
23	4										4
24	3										3
25		2									2
26		2	1								3
27		1	1								2
28		1	1								2
29		1	1		1						3
30		1	3	1	1	1					7
31			1	3	1						5
32			1		2						3
33				2	2	1					5
34			1	2	1						4
35				1	3		1				5
36				1	2	2	1				6
37			1		2		1	1			5
38				1		4	1				6
39						4	2	1			7
40						1	1	4			6
41					1	1	4	1			7
42						1	3	2	1		7
43							1				1
44						2		1		1	4
45							1	1			2
46											0
47									1		1
48											0
49											0
50											0
51											0
N	12	8	11	11	16	17	16	11	2	1	105
x	23.2	27.5	30.8	33.8	34.6	39.0	39.4	42.7	45.0	44.5	
sd	1.1	1.8	3.3	2.4	2.9	3.5	4.3	3.8	3.5		

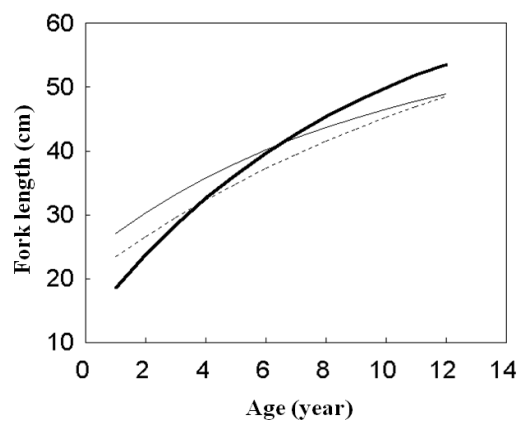


Fig. 1. The von Bertalanffy growth curves for *B. decadactylus* based on all individuals collected in each of the three archipelagos (—, Azores; ---, Canaries; ···, Madeira). See text for values of VB growth parameters.

Table 4. Results of the covariance analysis (Newman-Keuls test applied to compare the L paired means) for the three regions analysed.

Region	Canaries	Madeira	Azores
Canaries		0.0628	0.0949
Madeira	0.0628		0.5326
Azores	0.0949	0.5326	

Table 5. Growth performance indexes (Φ') for *B. decadactylus* in different geographical areas.

Area	Φ'	Authors
Canaries	2.57	Present work
Madeira	2.53	Present work
Azores	2.69	Present work
Azores	2.53	Isidro (1996)

DISCUSSION

The results obtained on age and growth of *B. decadactylus* in the Azores, Madeira and Canary Islands were found to be in good agreement. Similar fork lengths and age ranges were observed in the three archipelagos. The maximum estimated age for alfoncino specimens in the Azores was 10 years old (50 cm L_F), in Madeira 11 years (45 cm L_F), and in the Canaries 9 years (44 cm L_F). The apparent differences in the von Bertalanffy growth parameters between the Azores and the Canaries, and between the Azores and Madeira, were not statistically significant. The higher growth parameter estimates obtained for the Azores could be partially explained by the greater lengths found in the region and/or due to smaller sample sizes of older and young individuals from the other two regions. Isidro (1996) determined a slightly lower asymptotic length ($L_\infty=56.3$ cm L_F) for this species in the Azores than the present study. The k value (0.107 year^{-1}), however, was similar.

Overall, growth of *B. decadactylus* from these Macaronesian archipelagos was found to be relatively slow, with males and females having similar growth rates. This study also showed that *B. decadactylus* in Azores, Madeira and Canaries, have similar growth rates. This conclusion was supported by the fact that both the von Berta-

lanffy growth parameters and growth performance indexes were similar between the three regions, indicating similarity in growth patterns between stocks from the Macaronesian archipelagos analysed.

Slow growth and longevity are the norm in Berycidae (Rico et al. 2001), and typically, fisheries based on slow growing species are highly susceptible to growth overfishing, which is characterised by low yields as a result of large catches of small sized, immature fish. Estácio et al. (2001) determined the size at first maturity of *B. decadactylus* in Azores at 32 cm (age 4). Yet, according to the results, 30% of the specimens used in the present study, which were collected by a random length-stratified method from catches onboard commercial boats and research vessels in the three archipelagos, were less than 4 years old. Hence, more appropriate management measures for this species appear necessary in order to safeguard the spawning stock and recruits. We suggest that a minimum landing size for the species be introduced to enable more individuals to reach sexual maturity and contribute to the growth of the population.

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