ASPECTS OF AGE AND GROWTH OF BLUEMOUTH, *HELICOLENUS DACTYLOPTERUS DACTYLOPTERUS* (DELAROCHE, 1809) FROM THE AZORES

EDUARDO ESTEVES, JAIME ANÍBAL, HELENA KRUG & HELDER MARQUES DA SILVA

ESTEVES, EDUARDO, JAIME ANÍBAL, HELENA KRUG & HELDER MARQUES DA SILVA 1997. Aspects of age and growth of bluemouth, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809) from the Azores. *Arquipélago*. Life and Marine Sciences 15A: 83-95. Ponta Delgada. ISSN 0873-4704.

Bluemouth, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809), age and growth were studied by whole-view examination of left *sagittae* (n = 401) obtained from specimens (14-47 cm in total length) caught off the Azores. Opaque rings observed on the anti-sulcal surface of *sagittae* were enumerated as age estimates. Ages ranged from 3 to 14 years in males and 3 to 12 years in females. The von Bertalanffy growth equation was fitted to average length at age data, and compared between sexes and methods (direct examination of otoliths, backcalculation and length-frequency analysis). No important differences in growth between sexes were found. Results are different from published literature for the region. The causes and implications of the results are discussed.

ESTEVES, EDUARDO, JAIME ANÍBAL, HELENA KRUG & HELDER MARQUES DA SILVA 1997. Idade e crescimento do boca-negra, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809) dos Açores. *Arquipélago*. Ciências Biológicas e Marinhas 15A: 83-95. Ponta Delgada. ISSN 0873-4704.

A idade e o crescimento de boca-negra, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809), foram estudadas pela observação dos otólitos (*sagittae*) esquerdos inteiros (n = 401) obtidos de exemplares (14-47 cm de comprimento total) capturados em águas Açoreanas. Enumeraram-se os anéis opacos observados na face anti-sulcal dos otólitos. Os intervalos de idades foram 3-14 anos para machos e 3-12 anos para fêmeas. Estimaram-se e compararam-se os parâmetros da equação de crescimento de von Bertalanffy, entre sexos e entre métodos (leitura directa de otólitos, retrocálculo e análise de distribuições de frequências de comprimentos). Não se verificaram diferenças importantes. Os resultados são diferentes da literatura publicada para a região. Discutem-se as causas e implicações dos resultados obtidos.

Eduardo Esteves (e-mail: b005@lex.si.ualg.pt) & Jaime Aníbal, UCTRA, Universidade do Algarve, Campus de Gambelas, PT-8000 Faro, Portugal. - Helena Krug & Helder Marques da Silva, Universidade dos Açores, Departamento de Oceanografia e Pescas, PT-9900 Horta, Portugal.

INTRODUCTION

The bluemouth, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809), is a benthic (200-1000 m) fish species common in the Atlantic ocean from Norway to South-Africa, Azores, Madeira and Canaries, and in the Mediterranean Sea (QUÉRO 1984; HUREAU & LITVINENKO 1986). It is one of the three scorpaenid species of economic value captured by the Azorean artisanal that fishes for blackspot seabream (*Pagellus bogaraveo*)

(ISIDRO 1987b). The captures of bluemouth increased from 29% weight of the blackspot seabream landings reported in 1986 to 67% in 1995 (LOTAÇOR 1985/1995).

Information on age and growth of Atlantic bluemouth is sparse, being the aim of two study reports (ISIDRO 1987a, b). This author examined whole otoliths from monthly samples, and evidences of annual ring deposition and of differential growth between males and females were presented.

The aims of this study were to investigate the age and growth of the bluemouth, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809), from the Azores using the *sagittae* otoliths and to compare the results with published findings for the region.

MATERIAL AND METHODS

FISH SAMPLING AND OTOLITH PREPARATION

A total of 912 bluemouth specimens were caught at stations across the Azores archipelago, using bottom longline, aboard R/V "Arquipélago": in March-April 1995. From the fish sampled, total length (TL, to the lowest cm) was measured with a calliper, sex was determined macroscopically, and the otoliths (*sagittae*) were extracted, cleaned and stored dry. Otoliths were then sorted into four size classes (<25 cm, 25-30 cm, 31-35 cm, and >35 cm). In each class, about 100 otoliths were chosen randomly with the aid of a random numbers table (YAMANE 1964). Whole left *sagittae* (n = 401, 228 males and 173 females) were examined in 96% ethanol under a compound stereoscope with reflected light and a dark background. Opaque rings were counted on the anti-sulcal surface and around the otolith, mainly on the *rostrum*, *antirostrum* and ventral planes (Fig. 1). The otoliths were examined without the knowledge of length. The type of edge (translucent or opaque) of the otolith along the axis of measurement was also noted. Whenever interpretation of the otoliths imposed doubts the otoliths were discarded. A sub-sample of 183 *sagittae* previously read (112 males and 71 females) was chosen for ring measurement, according to assigned age, fish length and sex. Otoliths were analysed using image analysis software linked to a compound stereoscope equipped with a video camera. Measurements were made along the *rostrum* from the focus to the edge of the otolith (otolith radius, OR), and to the outer margin of each opaque ring (ring n radius, On).

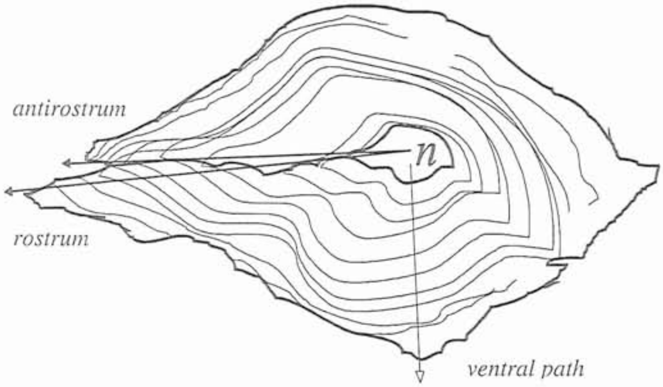

Fig. 1. Diagram of the anti-sulcal surface of a left *sagittae* of bluemouth, *Helicolenus dactylopterus dactylopterus*. Opaque rings are represented by fine lines and counting paths are indicated with arrows. Rostral length of otoliths observed varied between 3.15 mm and 10.06 mm. n - focus.

DATA ANALYSES

Age-length keys (ALK) based on the readings were constructed for males, females and both sexes combined. Mean TL (±SD) were calculated for each age.

The relationships between TL and otolith radius, and between otolith radius and ring counts were examined by regression analyses and the significance of the regressions values was tested (SOKAL & ROHLF 1981). Intercept and slope values were compared between males and females using the *t*-Test (SOKAL & ROHLF 1981). Lengths at age for individual fish were back-calculated using the Fraser-Lee linear method (FRANCIS 1990). Mean TL (± SD) was computed for each age.

Modes in the length-frequency distribution of specimens sampled during the cruise (n = 882, 487 males and 395 females) were separated using Bhattacharya's method (see SPARRE & VENEMA 1992) implemented in the LFSA-FAO package (SPARRE 1988). Two criteria were used to identify the modes, the separation index (SI), a ratio based on the difference between the means of the components and the average of correspondent standard deviations, and the correlation coefficients of the regression lines. Components showing a SI greater than 2.0 were considered to be meaningfully separated. The observed and expected distributions were compared by the Chi-square Test (SOKAL & ROHLF 1981).

Von Bertalanffy growth equations (BAGENAL & TESCH 1978) were fitted to mean lengths at age derived from age-length keys, backcalculation analysis, and length-frequency analysis using the FiSAT computer software (GAYANILO et al. 1994). To avoid possible biases, ages that represented less than 5% of total number of specimens aged were discarded from the analysis. Constraints were automatically set by the software. Equations maximising the Phi-prime (ϕ') Test's value (a maximum likelihood test for the comparison of overall growth performance. See SPARRE & VENEMA (1992)). and the coefficient of determination (r^2) were chosen.

RESULTS

Female bluemouth specimens ranged in length (TL) from 14 cm to 46 cm and were estimated to be 3 to 12 years, while males ranging in length from 15 to 47 cm were estimated to be 3 to 14 years. Age-length keys (ALK) and mean TL at age (observed length) are presented in Tables 1 and 2. For succeeding years the observed length increments were 3.4, 3.4, 3.5, 4.0, 2.3, 1.4, 4.5, -1.0 and 2.8 cm (12th year), and 2.2, 2.7, 2.0, 3.6, 3.1, 3.0, 3.8, 4.5 and 0.7 cm (12th year), in males and females respectively. Almost all otoliths, both male and female, presented translucent borders (97.7% of the females and 98.7% of the males).

The eight components identified in the length-frequencies distributions of males and females and the results of the analysis are summarised in Tables 3 and 4. The values calculated for the Separation Index (SI) were greater than 2.0. Expected and observed distributions were significantly different ($p<0.05$). The first component identified in the distribution was considered to be the third age group.

The relationships between *sagittae* radius (OR) and TL, for males, females and sexes combined, were best described by significant positive linear equations ($p<0.001$) (Table 5 and Fig. 2). Between males and females, intercepts were not significantly different (t' = 0.18, $p>0.05$), whereas equality of slopes was rejected (t' = 0.69, $p<0.05$). Ring counts (RC) increased with otolith growth. The relationships RC:OR were linear and statistically significant ($p<0.001$) (Table 5 and Fig. 3). Neither intercepts nor slopes differed between males and females (t = 1.67, $p>0.05$, and t = 1.39, $p>0.05$, respectively). Mean back-calculated lengths at age (BL) ranged from 15.8 cm to 43.4 cm in females (ages 3 to 12) and from 16.6 cm to 41.9 cm in males (ages 3 to 14) (Tables 6 and 7).

Table 1

Age-length key for female bluemouth, *H. dactylopterus dactylopterus*. CL - length classes (midpoint); N - number of individuals from which *sagittae* were examined; Mean TL - mean total length; and SD - standard deviation.

	Estimated age - Ring counts											
CL.	1	2	3	4	5	6	7	8	9	10	11	12
(...)												
14.5				1								
15.5			1									
16.5			2	1	1							
17.5			1	1								
18.5			1		1							
19.5				1								
20.5			1	1	1							
21.5			3			1						
22.5			1	3	2	3						
23.5			2	3	5							
24.5				1	3	3	3					
25.5					4	3						
26.5				2	8	4		1				
27.5				1	4	5	4	1				
28.5					6	4	2	1				
29.5					1	4	1	2				
30.5							1	2	3			
31.5						1	3	2	1			
32.5						1	4	6	1			
33.5							1	1	2			
34.5							1	1	2			
35.5							3	3	1			
36.5								2	2	1		
37.5									1			
38.5									3			
39.5								2	1	1		
40.5								1		1		
41.5									2			
42.5								1	3	2		
43.5											1	
44.5											1	
45.5												1
46.5											1	
N			12	15	37	29	23	26	22	5	3	1
Mean TL, cm			19.9	22.1	24.8	26.8	30.4	33.5	36.5	40.3	44.8	45.5
SD			2.75	3.65	4.99	2.64	3.44	3.96	4.02	2.23	1.25	0.00

The von Bertalanffy growth parameters computed for males and females, using data derived from length frequency analysis (LFA), age-lengths keys (ALK) and backcalculation (BL), and the resulting equations of growth in length are presented in Table 8 and graphed in Figs 4 and 5. Considering the standard error (SE) of parameters estimates (Table 8), equations derived from the age-length keys, backcalculation analysis and length-frequency analysis are similar in males and in females (Fig. 4). The growth curves based in ALK showed that females generally grow to a larger size for corresponding age, whereas in BL- and LFA-based growth curves the opposite occurs (Fig. 5).

Table 2

Age-length key for male bluemouth, *H. dactylopterus dactylopterus*. CL - length classes (midpoint); N - number of individuals from which *sagittae* were examined; Mean TL - mean total length; and SD - standard deviation.

	Estimated age - Ring counts													
CL.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
(...)														
15.5			1											
16.5														
17.5			1	1	1									
18.5			1											
19.5			2	3										
20.5			2	1	1									
21.5			3	3	2									
22.5					5	1								
23.5			1	2	2									
24.5				3	5	2								
25.5				1	3	3		1						
26.5				2	2	3	1							
27.5					1	3	3	1	2					
28.5					2	4	2	1						
29.5				1	4	4	2	2						
30.5					2	3	3	2	1					
31.5				1	5	5	3							
32.5					3	3	4							
33.5					1	6	1	3						
34.5						2	2	1						
35.5						2	2	2	1					
36.5						1	2	2		1	2			
37.5							4	4	2	1				
38.5						1	5	2	1					
39.5							3	7	2	1				
40.5							1	3	1		1	1		
41.5							1	1	1	4				
42.5							1	2	2					
43.5								2		1	1			1
44.5									1	2	3	1		1
45.5									1			1		
46.5										2		1		
47.5										1				
N			11	18	39	43	40	36	15	13	7	4		2
Mean TL, cm			20.0	23.4	26.8	30.3	34.3	36.6	38.0	42.5	41.5	44.3		44.0
SD			2.17	3.60	4.08	3.62	4.42	4.70	5.51	3.40	3.64	2.86		2.69

DISCUSSION

The issue of age determination in scorpaenid species is still open. Although basic criteria have been established, preparation procedures are not standardised. A number of authors have studied growth and determined age of *Sebastes* spp. (BRATBERG 1949; NI & SANDEMAN 1984; LILLY 1987; MAYO et al. 1990; PEARSON et al. 1991; WOODBURY AND RALSTON 1991), but only the reports of ISIDRO (1987a, b) are available on Atlantic bluemouth age and growth.

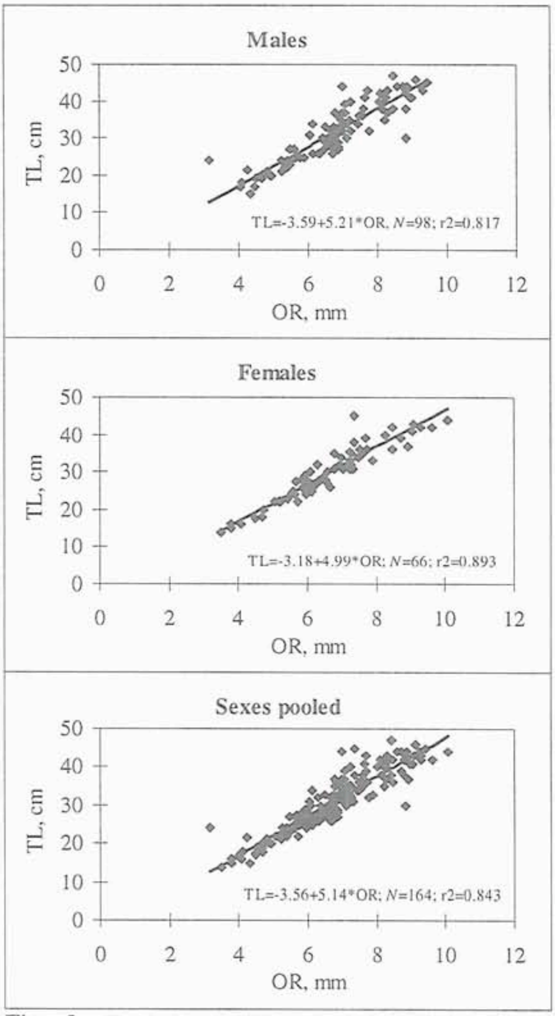

Fig. 2. Total length (TL) : otolith radius (OR) relationships for bluemouth, *Helicolenus dactylopterus dactylopterus*, caught off the Azores.

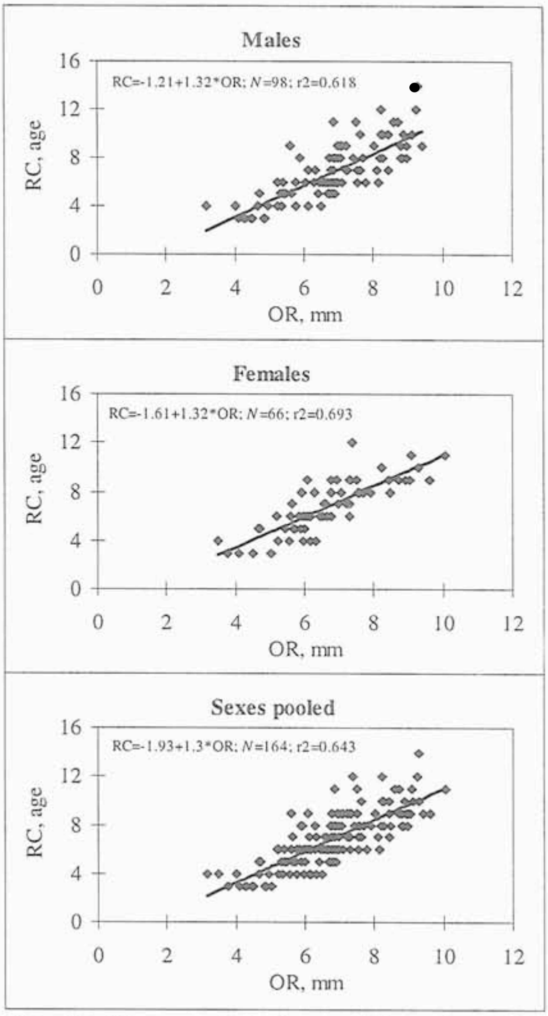

Fig. 3. Ring count (RC) : otolith radius (OR) relationships for bluemouth, *Helicolenus dactylopterus dactylopterus*, caught off the Azores.

Although no problems associated with age determination of bluemouth or other scorpaenids are mentioned in the literature, MACEINA & BETSILL (1987) stated that whole-view examination of otoliths may not allow accurate age interpretation for species that have thick otoliths, and are slow growing or display considerable longevity, as seem to be the case for bluemouth.

Various alternative methods have been proposed, namely "polishing and etching" (WIEDEMANN SMITH 1968), "etching and staining" (ALBRECHTSEN 1968), "burning and breakage" (CHRISTENSEN 1964), "sectioning" (BEAMISH & MCFARLANE 1987), etc., but discussion continues. Neglecting experimentation and blind reliance on "standard" or established techniques will impede the flexibility and ingenuity necessary to develop reliable otolith-ageing methods (BROTHERS 1987). Sectioning and "breaking and burning" of scorpaenid otoliths, namely from *Sebastes* spp., have provided considerably older age estimates than the

Table 3

Female length-frequency analysis output from LFSA-FAO software (SPARRE 1988). SD - standard deviation of estimate mean total length (TL); N' - calculated number of individuals; and SI - separation index.

Component	*Mean TL, cm*	*SD*	*N'*	*SI*
1	16.8	0.77	8	---
2	20.0	0.79	29	4.07
3	25.0	2.78	123	2.81
4	29.4	1.19	46	2.21
5	33.0	1.11	57	3.17
6	36.5	0.80	31	3.71
7	39.0	0.80	20	3.26
8	42.4	0.58	9	4.85

Table 4

Male length-frequency analysis output from LFSA-FAO software (SPARRE 1988). SD - standard deviation of estimate mean total length (TL); N' - calculated number of individuals; and SI - separation index.

Component	*Mean TL, cm*	*SD*	*N'*	*SI*
1	15.7	1.74	5	---
2	23.5	1.85	107	4.38
3	27.8	0.81	42	3.2
4	31.4	1.37	66	3.36
5	37.2	1.07	67	5.14
6	40.2	1.17	63	2.27
7	43.5	0.99	36	2.99
8	46.0	0.87	5	2.71

Table 5

Regression parameters for the relationships between otolith radius (OR) and total length (TL)/ring count (RC). a - intercept; b - slope; r^2 - coefficient of determination; N - number of specimens; *** - highly significant ($p<0.001$).

	a (±SE)	b (±SE)	N	r^2
TL:OR				
Males	-3.59 (1.749)	5.21 (0.252)	98	0.817 ***
Females	-3.18 (1.462)	4.99 (0.216)	66	0.893 ***
Sexes pooled	-3.56 (1.202)	5.14 (0.175)	164	0.843 ***
RC:OR				
Males	-2.21 (0.739)	1.32 (0.106)	98	0.618 ***
Females	-1.61 (0.713)	1.26 (0.105)	66	0.693 ***
Sexes pooled	-1.93 (0.522)	1.3 (0.076)	164	0.643 ***

examination of whole otoliths, registering maximum ages of 36 to 140 years (BEAMISH & MCFARLANE 1987).

ISIDRO (1987a) stated that one of either the *sagittae* can be used for age reading in bluemouth. In the present study the choice for the left *sagittae* allowed direct comparisons with previous studies. All the paths used for counting otolith rings presented difficulties of interpretation. The opaque rings observed on

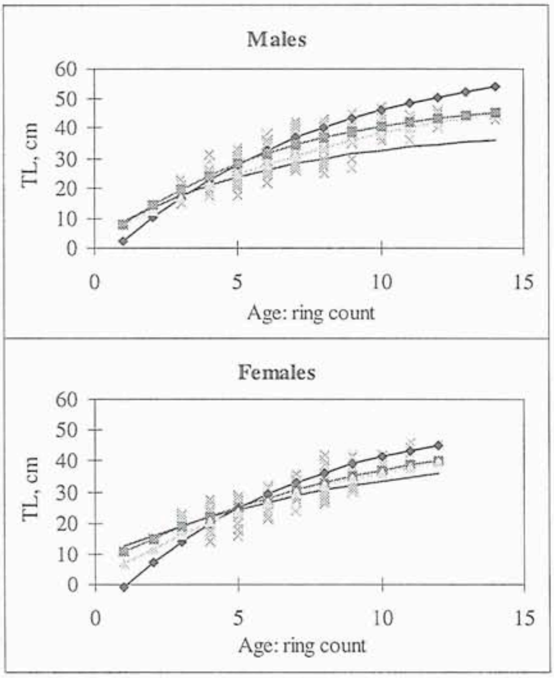

Fig. 4. von Bertalanffy growth curves for bluemouth, *Helicolenus dactylopterus dactylopterus*, from the Azores. Included are original age-length data and curves derived from: age-length keys (squares); length-frequency analysis (diamonds); and backcalculation analysis (triangles). Also included are VB growth curves (solid line) published by ISIDRO (1987a).

the dorsal side of otoliths were usually crowded, while heavier material deposition occurred in the *rostrum* and *antirostrum* of otoliths from larger specimens. Moreover, ISIDRO (1987a) stated that reading along the posterior part of the otoliths was most difficult.

The percentages of translucent borders observed in March-April are higher than the values found by other authors and seem to confirm the annual nature of increment deposition reported by ISIDRO (1987b) for bluemouth and by BRATBERG (1949) for *Sebastes marinus*. ISIDRO (1987b) found that the percentage of otoliths with translucent borders is high during Fall and Winter (maximum of 70-80% in March), decreasing during Spring and reaching its minimum in the

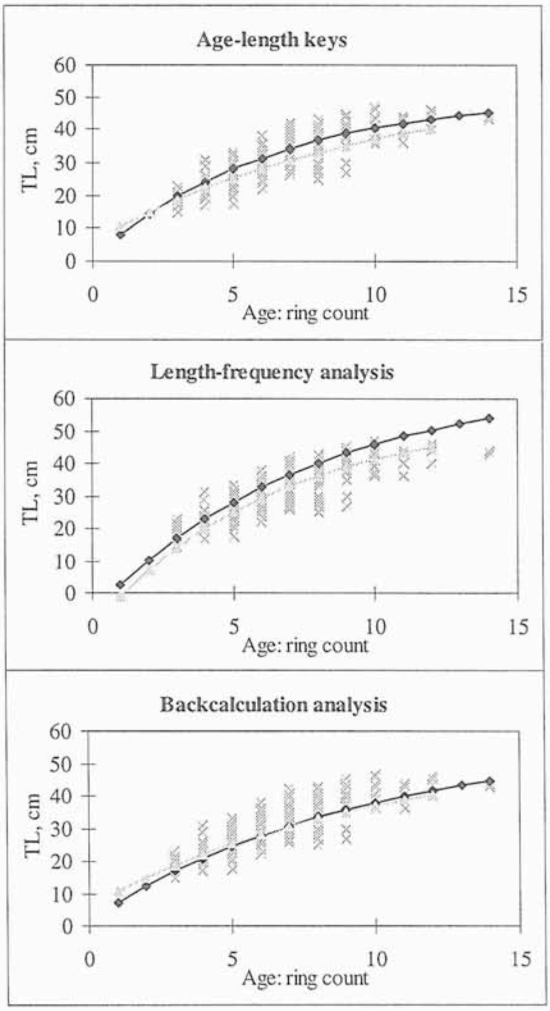

Fig. 5. von Bertalanffy growth curves derived for male and female bluemouth, *Helicolenus dactylopterus dactylopterus*, based on three different methods. Males - diamonds and Females – triangles.

Summer months (less than 35% in August).

The last ring on the edge of the otolith, whether opaque or translucent, may be difficult to interpret as an annual ring because of variations in its size and nature. Nevertheless, correct interpretation is critical in order to assign a fish to the proper year class or age group (ICSEAF 1983).

Table 6

Back-calculated lengths (TL, cm) of female bluemouth from the Azores. Values are means with SD in parentheses; Mean TL - mean total length, cm; SD - standard deviation; N - number of fish read in each sample; ... - ring measurements could not be made along the chosen path.

Ring counts		Mean length (TL, cm) at various ages											
	N	1	2	3	4	5	6	7	8	9	10	11	12
3	*5*	7.5	11.7	16.2									
		(1.27)	(1.73)	(2.08)									
4	*6*	9.4	13.8	18.5	23.8								
		(1.76)	(1.38)	(1.62)	(1.93)								
5	*8*	7.2	10.5	14.5	18.4	22.0							
		(2.34)	(2.42)	(2.66)	(3.48)	(3.57)							
6	*12*	8.3	12.4	15.9	20.0	23.5	25.9						
		(1.69)	(2.1)	(2.63)	(2.85)	(3.15)	(2.95)						
7	*8*	8.0	12.6	15.6	19.1	22.4	26.9	30.3					
		(2.51)	(2.87)	(3.07)	(3.18)	(3.44)	(4.23)	(4.07)					
8	*8*	7.5	11.6	16.0	19.4	22.8	25.9	29.2	32.0				
		(1.91)	(2.46)	(2.06)	(3.05)	(3.82)	(3.57)	(2.83)	(2.73)				
9	*11*	7.5	11.2	15.8	19.6	23.0	26.3	29.6	33.0	35.0			
		(2.28)	(2.23)	(2.74)	(3.55)	(3.35)	(3.7)	(3.63)	(3.59)	(3.88)			
10	*1*	4.2	10.5	15.8	20.4	26.2	29.5	32.8	37.2	38.8	...		
12	*1*	...	...	...	19.1	21.8	24.2	27.0	30.4	32.8	35.5	39.2	43.4
TL		7.7	11.8	15.8	19.7	22.9	26.2	29.7	32.7	35.1	35.5	39.2	43.4
SD		2.16	2.36	2.62	3.30	3.29	3.42	3.41	3.26	3.76	0	0	0
N		59	59	58	54	48	41	29	21	13	1	1	1

The type of relationship between OR and TL and associated parameters, determines the method of backcalculation to use. On the other hand, a paradigm of the ageing theory is that the number of increments in or on the hard part increases with the growth of the structure (BROTHERS 1983). The significance of the regression lines fitted to the TL:OR and RC:OR data reinforced the use of otoliths for age determination in bluemouth. Differences in the slope of the TL:OR relationships between males and females might lead us to expect different growth between males and females. Furthermore, ISIDRO (1987a) found significant differences between males and females in the slopes of the regressions lines derived for the OAR (otolith anterior radius):TL relationships.

The standard errors (SE) associated with some of the estimated von Bertalanffy (VB) parameters (Table 8) emphasise the dispersion of the original age estimates and advise caution when using the equations for further analysis. Nevertheless, von Bertalanffy "theoretical" lengths could be useful when restricted to the age range considered for estimation. The species is predicted to grow to 50-65 cm TL at a relatively slow rate, $k = 0.101 - 0.163$ (Table 8).

The TL values predicted by the VB equations are generally higher than those published by ISIDRO (1987b). The increase in the fisheries' captures, with landings rising from 191.8 tonnes in 1985 to 947.5 tonnes in 1995 (LOTAÇOR 1985/1995), and the possible corresponding decrease in population density, could be responsible for some "compensatory" density-dependent growth of the population, as noted by NIELSEN (1973), WEATHERLEY (1976) and HOUGHTON (1979) for demersal fish species. Furthermore, von Bertalanffy growth rates, k, estimated in the present study for females are less than those reported by ISIDRO (1987a, b), whereas k calculated for males are greater. The growth rate values

Table 7

Back-calculated lengths (TL, cm) of male bluemouth from the Azores. Values are means with SD in parentheses; Mean TL - mean total length, cm; SD - standard deviation; *N* - number of fish read in each sample.

Ring counts		Mean length (TL, cm) at various ages													
	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14
3	*7*	7.5	12.7	17.6											
		(1.17)	(2.07)	(1.93)											
4	*9*	8.1	13.5	18.6	21.9										
		(1.82)	(2.29)	(4.06)	(3.73)										
5	*15*	8.3	12.4	17.6	22.0	25.5									
		(1.80)	(2.01)	(2.55)	(2.97)	(3.36)									
6	*17*	8.1	12.7	16.7	21.4	25.6	28.4								
		(1.04)	(2.35)	(3.01)	(3.36)	(4.03)	(3.87)								
7	*13*	7.8	12.6	16.7	20.6	25.0	28.9	32.3							
		(2.72)	(2.69)	(3.65)	(4.24)	(4.57)	(5.37)	(5.59)							
8	*14*	7.9	12.5	16.4	20.9	24.6	27.9	31.1	34.1						
		(3.16)	(3.70)	(4.22)	(5.12)	(5.58)	(5.84)	(5.82)	(6.18)						
9	*9*	7.5	12.2	15.2	18.8	22.6	26.1	30.0	33.5	36.4					
		(2.82)	(2.78)	(3.42)	(4.24)	(5.01)	(5.00)	(5.98)	(6.17)	(6.21)					
10	*6*	7.6	12.6	16.7	20.7	25.8	30.5	35.1	37.6	40.6	42.5				
		(1.6)	(3.79)	(3.67)	(4.91)	(4.46)	(4.85)	(4.7)	(4.36)	(3.06)	(2.99)				
11	*4*	6.4	9.6	12..6	16.3	20.0	22.6	26.4	30.4	33.1	36.4	38.8			
		(2.73)	(2.64)	(2.86)	(3.46)	(4.46)	(5.08)	(6.10)	(4.86)	(4.82)	(4.46)	(4.33)			
12	*2*	5.7	8.4	12.6	15.3	19.6	23.5	27.0	30.9	34.8	38.1	40.3	42.5		
		(0.39)	(0.03)	(0.79)											
14	*1*	5.1	8.4	11.7	16.0	22.3	25.6	27.0	29.6	32.3	34.0	36.2	38.8	40.3	41.9
Mean TL		7.8	12.4	16.6	20.7	24.5	27.7	31.0	33.8	36.5	39.1	38.6	40.6	40.3	41.9
SD		2.22	2.74	3.49	4.11	4.55	5.1	5.77	5.76	5.47	4.55	3.61	2.59	0	0
N		97	95	94	86	77	62	47	34	20	11	6	2	1	1

might be related to the reproductive behaviour of the species: females spawn from January to April, and males sexual maturation peaks in September (ISIDRO 1987b), with females redirecting their growth strategy to the reproductive tissues during that period.

The estimation of von Bertalanffy growth equation parameters was surely affected by the trend in length increments for succeeding years (*cf.* Results) and/or by age estimates. Mean annual increments are expected to decrease linearly after a certain moment in fish growth history (GULLAND 1983; GUTREUTER 1987). The pattern observed in this study for female bluemouth was somewhat different, as the annual growth increments were nearly constant over time. A similar trend was found by BRATBERG (1949) for Norwegian *S. marinus*. On the other hand, misinterpretation of otolith features namely the enumeration of false rings, checks, splits, etc., which constitute the main source of difficulty in the interpretation of the whole otolith (WILLIAMS & BEDFORD 1974), might be responsible for the dispersion observed (cf. Figs 4 and 5). Finally, and according to SPARRE & VENEMA (1992) it is often very difficult to obtain an unambiguous interpretation of a length-frequency data set, in particular when there is only one complex length-frequency sample available and not a time series, which is the case of this study. Therefore, inaccurate identification of modes might have been responsible for some of the differences observed in estimates.

The general similarity between von Bertalanffy growth equations derived from the methods employed in the present study may be indicative that the differences between sexes found when analysing TL:OR relationships are in fact less important or irrelevant. This could be responsible for the differences found when comparing male and female VB equations

Table 8

Parameters of the von Bertalanffy growth equations obtained in this study for males and females using various methods. ALK - age-length key; BL - backcalculation analysis; LFA - length-frequency analysis; SE - standard error of estimates; r^2 - coefficient of determination; ϕ'- Phi-prime Test value; * - maximum constraint of FiSAT fitting routine.

Parameters	$L\infty$ (±SE)	k (±SE)	t_o (±SE)	*ages*	r^2	ϕ'
ALK						
Females	*54.7 (25.6)	0.101 (0.096)	-1.156 (1.774)	3-9	0.974	2.48
Isidro, 1987	39.37	0.1696	-0.4592			
Males	50.2 (3.26)	0.163 (0.033)	0.051 (0.532)	3-10	0.984	2.61
Isidro, 1987	45.94	0.1099	-1.888			
BL						
Females	*52.6 (6.43)	0.114 (0.024)	-0.237 (0.208)	1-9	0.996	2.5
Males	57.4 (4.40)	0.105 (0.015)	-0.317 (0.178)	1-11	0.997	2.54
LFA						
Females	56.0 (1.95)	0.151 (0.011)	1.078 (0.114)	4-9	0.999	2.68
Males	*65.3 (19.68)	0.131 (0.084)	0.709 (0.981)	4-9	0.989	2.75

derived from back calculated lengths. As a consequence of the problems discussed above, and despite the apparent similarity in growth between sexes, the data for both sexes were not pooled.

Use of inaccurate ages has caused serious errors in the management and understanding of fish populations. Only by mark-recapture studies or use of known-age fish can all age-classes in a population be validated. If such studies are not possible, fish should be aged by several methods and the results compared, e.g. whole-view examination *vs.* breaking-and-burning (see PEARSON et al. 1991) or sectioning *vs.* whole-view examination. In the present study, the use of whole-view examination of otoliths permitted the direct comparison with published results for the region. In addition, samples obtained during at least a year and covering the widest possible length range should be used. The possibility of errors in age estimates must also be considered (BEAMISH & MCFARLANE 1983). Further analysis of precision and accuracy (CASSELMAN 1983; BRENNAN & CAILLIET 1989) of age estimates is essential for the understanding of bluemouth age and growth from the Azores. Methods for precision analysis are presented by BEAMISH & FOURNIER (1981) and CHANG (1982).

ACKNOWLEDGEMENTS

This work is part of a more comprehensive study which is being done at the Department of Oceanography and Fisheries of the University of the Azores with support of the European Union (Design optimization and implementation of demersal survey cruises in the Macaronesian archipelagos. Study contract 94/034). Thanks are due to Drs. Pedro Andrade, Emygdio Cadima and Manuel Afonso Dias for help with and discussion of various aspects of this paper. We are also grateful to two anonymous referees for their suggestions and pertinent comments.

REFERENCES

ALBRECHTSEN, K. 1968. A dyeing technique for otolith reading. *Journal du Conseil Permanent International pour l'Exploration de la Mer* 32(2): 278-80.

BAGENAL, T.B. & F.W. TESCH 1978. Age and Growth. Pp. 101-136 in: BAGENAL, T.B. (Eds.) *Methods for the assessment of fish production in freshwater*. Blackwell Scientific Publications, Oxford.

BEAMISH, R.J., & D.A. FOURNIER 1981. A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Aquatic Sciences* 38(8): 982-983.

BEAMISH, R.J. & G.A. MCFARLANE 1983. The forgotten requirement for age validation in fisheries biology. *Transactions of the American Fisheries Society* 112(6): 735-743.

BEAMISH, R.J. & G.A. MCFARLANE 1987. Current trends in age determination methodology. Pp. 15-42 in: R.C. SUMMERFELT & G.E. HALL (Eds.) *The age and growth of fish*. The Iowa State University Press, Ames. 544 pp.

BRATBERG, E. 1949. On the interpretation of the opaque and hyaline zones in the otoliths of immature redfish (*Sebastes marinus* L.). *Journal du Conseil Permanent International pour l'Exploration de la Mer* 16(1): 66-74.

BRENNAN, J.S. & G.M. CAILLIET 1989. Comparative age-determination techniques for white sturgeon in California. *Transactions of the American Fisheries Society* 118: 296-310.

BROTHERS, E.B. 1983. Summary of the round table discussions on age validation. Pp. 35-44 in: PRINCE, E.D. & L.M. PULOS (Eds). *Proceedings of the International Workshop on age determination of oceanic pelagic fishes: tunas, billfishes, and sharks*. U.S. Department of Commerce, N.O.A.A. Technical Reports N.M.F.S. 8.

BROTHERS, E.B. 1987. Methodological approaches to the examination of otoliths in aging studies. Pp. 319-330 in: R. C. SUMMERFELT & G. E. HALL (Eds). *The age and growth of fish*. The Iowa State University Press, Ames. 544 pp.

CASSELMAN, J.M. 1983. Age and growth assessment of fish from their calcified structures - techniques and tools. Pp. 1-17 in: PRINCE, E.D. & L.M. PULOS (Eds.) *Proceedings of the International Workshop on age determination of oceanic pelagic fishes: tunas, billfishes, and sharks*. U.S. Department of Commerce, N.O.A.A. Technical Reports N.M.F.S. 8.

CHANG, W.Y.B. 1982. A statistical method for evaluating the reproducibility of age determination. *Canadian Journal of Fisheries and Aquatic Sciences* 39(8): 1208-1210.

CHRISTENSEN, J.M. 1964. Burning of otoliths, a technique for age determination of soles and other fish. *Journal du Conseil Permanent International pour l'Exploration de la Mer* 29(1): 73-81.

FRANCIS, R.I.C.C. 1990. Back-calculation of fish length: a critical review. *Journal of Fish Biology* 36(6): 883-902.

GAYANILO, F.C., P. SPARRE & D. PAULY 1994. *FiSAT. The FAO-ICLARM Stock Assessment Tools User's Guide*. Food and Agriculture Organisation of the United Nations, Rome.

GULLAND, J.A. 1983. *Fish stock assessment. A manual of basic methods*. John Wiley & Sons, Chichester. 223 pp.

GUTREUTER, S. 1987. Considerations for estimation and interpretation of annual growth rates. Pp. 115-126 in: R.C. SUMMERFELT & G.E. HALL (Eds). *Age and growth of fish*. Iowa State University Press, Ames. 544 pp.

HOUGHTON, R.G. 1979. Density-dependent growth in demersal fish. *International Council for the Exploration of the Sea* CM 1979/G: 22. 8 pp.

HUREAU, J.-C. & N.I. LITVINENKO 1986. Scorpaenidae. Pp. 1211-1229 in: WHITEHEAD, P.J.P., M.-L. BAUCHOT, J.-C. HUREAU, J. NIELSEN & E. TORTONESE (Eds.) *Fishes of the North-eastern Atlantic and the Mediterranean*. Volume III. UNESCO, Paris. 1473 pp.

I.C.S.E.A.F. 1983. *ICSEAF otolith interpretation guide. No.1 Hake*. International Commission for the Southeast Atlantic Fisheries 1: 70 pp.

ISIDRO, E.J. 1987a. Age and growth of the bluemouth, *Helicolenus dactylopterus dactylopterus* (De la Roche, 1809) off the Azores. International Council for the Exploration of the Sea CM 1987/G: 63. 6 pp.

ISIDRO, E.J. 1987b. Contribuição para o estudo da biologia e pesca de Boca Negra, *Helicolenus dactylopterus* (De la Roche, 1809) dos Açores. Pp. 183-189 in: ANONYMOUS (Eds.) *Relatório da 7ª Semana das Pascas dos Açores*. Secretaria Regional da Agricultura e Pescas, Direcção Regional das Pescas, Horta, 269 pp.

LOTAÇOR 1985/1995. *O pescado desembarcado nos Portos da Região Autónoma dos Açores*. Elementos estísticos do Serviço Açoreano de Lotas, E.P. - Lotaçor. Anuários relativos aos anos de 1985 a 1995.

LILLY, G.R. 1987. Synopsis of research related to recruitment of Atlantic cod (*Gadus morhua*) and Atlantic redfishes (*Sebastes* sp.) on Flemish Cap. *North Atlantic Fishery Organisation Scientific Council Studies* (11): 109-122.

MACEINA, M.J. & R.K. BETSILL 1987. Verification and use of whole otoliths to age white crappie. Pp. 267-278 in: R.C. SUMMERFELT & G.E. HALL (Eds.) *Age and growth of fish*. Iowa State University Press, Ames. 544 pp.

MAYO, R.K., J. BURNETT, T.D. SMITH & C.A. MUCHANT 1990. Growth.maturation interactions of Acadian redfish (*Sebastes fasciatus* Storer) in the Gulf of Maine-Georges Bank region of the Northwest Atlantic. *Journal du Conseil Permanent International pour l'Exploration de la Mer* 46(3): 287-305.

NI, I.-H. & E. J. SANDEMAN 1984. Size at maturary for northwest Atlantic redfishes (Sebastes). *Canadian Journal of Fisheries and Aquatic Sciences* 41(12): 1753-1762.

NIELSEN, E. 1973. On the density dependence of growth in soles (*Solea solea*). *Aquaculture* 1: 349-357.

PEARSON, D.E., J.E. HIGHTOWER & J.T.H. CHANG 1991. Age, growth, and potential yield for shortbelly rockfish *Sebastes jordani*. *Fishery Bulletin* 89(3): 403-409.

QUÉRO, J.-C. 1984. *Les poissons de mer des pêches françaises*. Maquette Dominique and Phillipe Lemonnier, Paris. 394 pp.

SOKAL, R.R., & F.J. ROHLF 1981. *Biometry. The principles and practice of statistics in biological research* (2nd Ed.). W.H. Freeman and Company, New York. 772 pp.

SPARRE, P. 1988. *Package of length based stock assessment programs*. FAO Marine Resources Services, Rome. (Software).

SPARRE, P. & S.C. VENEMA 1992. Introduction to tropical fish stock assessment. Part I - Manual. *FAO Fisheries Technical Paper* 306(1): 376pp.

WEATHERLEY, A.H. 1976. Factors affecting maximization of fish growth. *Journal of the Fisheries Research Board of Canada* 33: 1046-1058.

WIEDEMANN SMITH, S. 1968. Otolith age reading by means of surface structure examination. *Journal du Conseil Permanent International pour l'Exploration de la Mer* 32(2): 270-277.

WILLIAMS, T. & B.C. BEDFORD 1974. The use of otoliths for age determination. Pp. 114-123 in: BAGENAL, T.B. (Eds.) *The ageing of fish*. Unwin Brothers Ltd., England.

WOODBURY, D. & S. RALSTON 1991. Inter-annual variation in growth rates and back-calculated birthdate distributions of pelagic juvenile rockfishes (Sebastes). *Fishery Bulletin* 89(3): 523-533

YAMANE, T. 1964. *Statistics, an introductory analysis* (2nd Edition). Harper & Row Publishers, New York. 919 pp.

Accepted 31 July 1997