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Age and growth of bogue, *Boops boops*, in Tunisian waters

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*The age and growth of bogue (*Boops boops*), collected in four areas off the Tunisian coast, were determined by studying growth marks on cross-sectioned otoliths. This calcified structure was chosen because the legibility and regularity of its growth mark patterns appeared to be more reliable than those of other skeletal elements. Opercula and fin rays were rejected because of intense bone remodeling, vertebrae because of numerous minute marks unrelated to cyclic events, and scales because counting of annuli seemed very unreliable, particularly in old specimens. Scales consistently had the highest average percent of error.*

Marginal zone analysis indicated that the hyaline zone in bogue otoliths was deposited yearly from November to April. Increase of length was determined and length-age data were fitted to Von BERTALANFFY equations. Comparisons of length increases of specimens from the four areas suggest two growth pools with greater increases in the north and east than in the Gulf of Tunis and the south. Relationships between growth and geographical distribution indicated the importance of environmental conditions especially water temperature and food availability, although the role of genetic and/or epigenetic factors could not be excluded.

Key words: *Boops boops*, Tunisian coast, age, growth, sclerochronology, otolithometry

INTRODUCTION

The bogue, *Boops boops* (LINNÉ, 1758), is a teleost belonging to the sparid family. It is very abundant and supports large fisheries along the Tunisian coast (landings reached 3435 tons in 2003; GAAMOUR *et al.*, 2005). Accurate knowledge about age and growth are required to manage bogue fisheries (MILLS & BEAMISH, 1980; PANFILI *et al.*, 2002). However data on age and growth in Tunisian waters, as opposed to other areas, are very limited and are restricted to the study of ANATO & KTARI (1986).

Age in bogue has been estimated by methods based on length frequency analyses (ANDREU & RODRIGUEZ-RODA, 1951; GIRARDIN & QUIGNARD, 1986; TSANGRIDIS & FILIPPOUSIS, 1991) or sclerochronology based on the analysis of growth marks such as scale annuli (VIDALIS, 1950; ZUNIGA, 1967; ANATO & KTARI, 1986; GIRARDIN & QUIGNARD, 1986) or rings of *in toto* otoliths (ANATO & KTARI, 1986; ALEGRÍA HERNANDEZ, 1989; GORDO, 1996). Few studies dealing with skeletal structures report on validated age estimations since these structures were often randomly used (GIRARDIN & QUIGNARD, 1986; GORDO, 1996). Despite difficulties in interpreting growth mark patterns in some skeletal structures (GIRARDIN & QUIGNARD, 1986; ALEGRÍA HERNANDEZ, 1989), age can be reliably estimated by examining skeletal elements such as fin rays (BEAMISH & CHILTON, 1977; MEUNIER & PASCAL, 1981; BOUJARD & MEUNIER, 1991; MEUNIER *et al.*, 2002), vertebrae (MARZOLF, 1955; MEUNIER *et al.*, 1979; CLAY, 1982; PANFILI & LOUBENS, 1992), or the opercular bone (LECOMTE *et al.*, 1993), depending on the species.

The aims of the present study were to discover which skeletal structure (i.e., dorsal fin ray, opercular bone, otolith, scales, or vertebrae) provides the most reliable age estimation for bogue and the best and easiest technique for estimating age and growth in bogue, and to compare growth of bogues from four areas along the Tunisian coast.

MATERIAL AND METHODS

Samples were collected monthly from February 2000 to March 2002 in four areas along the Tunisian coast (Fig. 1): the north (36°58'N; 8°40'E to 37°10'N; 10°16'E), the Gulf of Tunis (37°10'N; 10°16'E to 37°04'N; 11°02'E), the east (37°04'N; 11°02'E to 35°N; 11°E), and the south (35°N; 11°E to 33°20'N; 11°40'E). The samples were provided by commercial and hydroacoustic survey catches.

Three thousand individuals were collected and their fork length (L_F) was measured to the nearest mm. L_F varied from 6.1 to 26 cm (Fig. 2) and one specimen was found with a fork length of 32 cm.

In order to choose the most reliable calcified structure for aging, the scales, otoliths (sagittae), vertebrae, left opercula, and third dorsal fin rays were removed from 30 specimens as indicated by PANFILI (1992) from specimens whose fork lengths were representative of the bogue population. Eight scales were taken from the left side of each individual, above the lateral line at the midpoint, and the left opercular bone was removed. The scales and opercular bone were cleaned, dried, mounted between two glass slides, and viewed with a binocular using naturally transmitted light. The otoliths and vertebrae were embedded in stratyl resin and sectioned with a low-speed Isomet saw. The sections were smoothed with 1200 sandpaper and polished with 0.3 µm Alumina micro polish on a velvet cloth. The sections were observed using a binocular with dark-field reflected light. The third dorsal fin rays were cleaned, dried, decalcified with nitric acid (3%) for 12 h, embedded in ice, and sectioned perpendicularly to their longitudinal axes. The sections were stained with EHRLICH's hematoxylin (PANFILI *et al.,* 2002), mounted between two glass slides, and observed with a microscope using naturally transmitted light. For each difficult piece, two readers made two examinations.

To assess the accuracy of the aging from reading the different structures, two statistical tests were performed: (1) Average Percent Error (APE) to evaluate the precision of

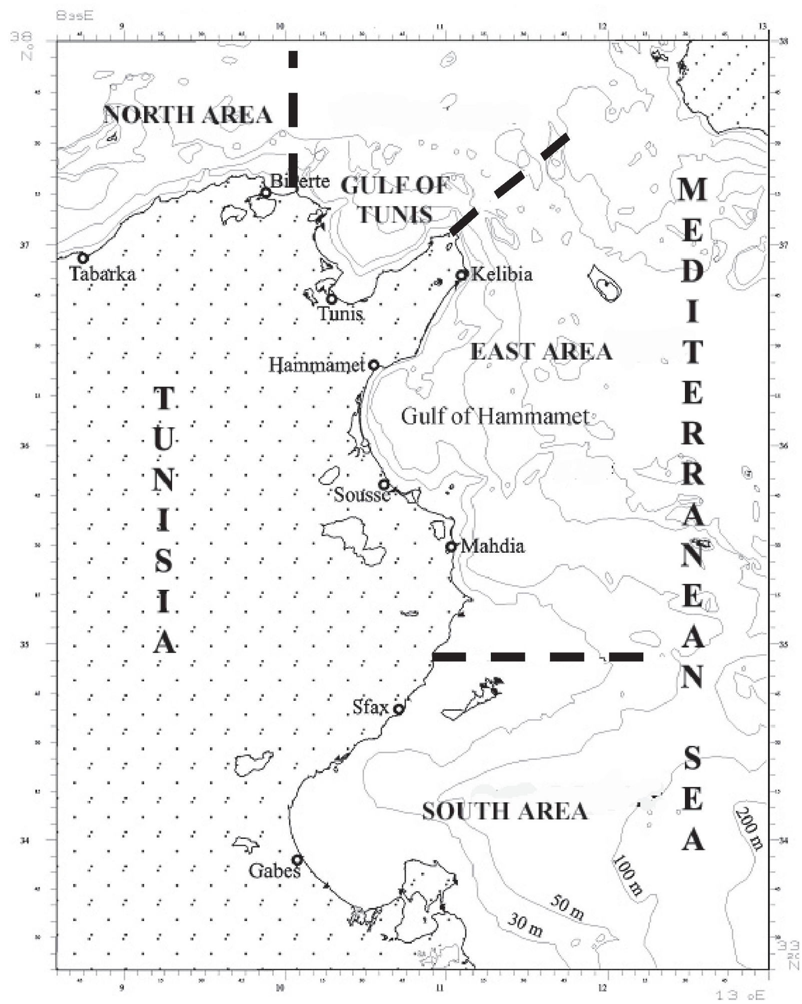

Fig. 1. Map of the Tunisian coast showing sampling areas separated by dashed lines

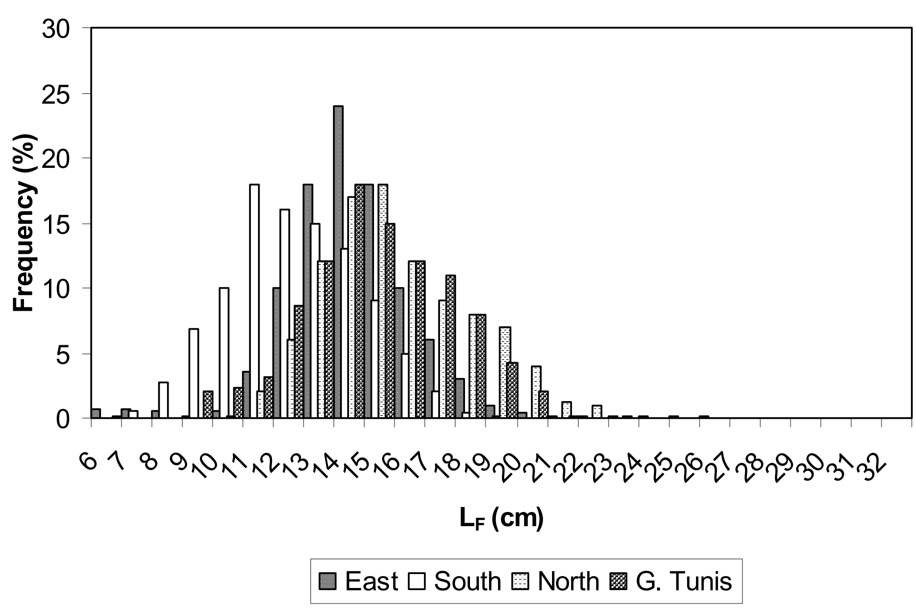

Fig. 2. Length distribution of bogue from the different areas

age determination (BEAMISH & FOURNIER, 1981); a low APE indicates good precision; APE = $[1/R \sum^{R}_{i=1}(|X_{ij}-X_j)/X_j)]$ x 100 where R is the number of readings, X_{ij} is the i^{th} age estimation from the j^{th} fish, and X_j is the mean age of the j^{th} fish; and (2) the WILCOXON test (SCHWARTZ, 1993), a distribution-free test used to compare the ages obtained from different calcified structures.

The incremental growth pattern of cross-sectioned otoliths was determined from the monthly formation of the hyaline zone at the growing edge (BEAMISH & MAC FARLANE, 1987; PANFILI, 1992). The analysis used qualitative data by evaluating the presence or absence of the growth mark and the monthly relative marginal distance (RMD) of quantitative marks. The RMD fell when a new hyaline zone began to form and increased when an opaque zone was deposited. A stabilized RMD value indicates that the otolith stopped growing. If growth marks form yearly, the RMD should show one peak corresponding to the period of opaque zone formation. Measurements were made along a standard axis: the shortest. RMD = AMD/D where AMD is the distance between the last mark and the edge and D is the distance between the two last marks.

The age readings were carried out on 1006 cross-sectioned otoliths pooled for each area (223 individuals in the north, 230 individuals in the Gulf of Tunis, 298 individuals in the east, and 253 individuals in the south). Otolith cross-sections from juvenile bogues were examined to determine the location of the first seasonal zone (hyaline zone). The age of each specimen was determined by taking into account the annual formation and number of hyaline zones, the date of capture, and the theoretical date of birth (March 15; unpublished results). The age-length data of each area were fitted to the Von BERTALANFFY model (BERTALANFFY, 1938) by the Quasi NEWTON non-linear method using Statistica Statsoft. The Von BERTALANFFY Model is: $l_t = L_\infty (1 - \exp(-k(t - t_0)))$ where t is age in years, l_t is estimated length at age t, L_∞ is the asymptotic length, k is a growth constant, and t_0 is an extrapolated constant. In our study we have used the fork length as a reference length to fit the Von BERTALANFFY model.

The STUDENT *t* test was performed to compare length increases in each age group among areas. Differences were considered significant when the α-level (risk level) was 0.05.

RESULTS

Assessment of aging

The opercular bones were thick approximately-triangular plates. Because of their thickness, they were opaque. The growth marks were often unclear and/or incomplete due to important remodeling processes. Vertebrae sections had numerous minute growth marks that were obviously unrelated to cyclic events. The thin elasmoid scales were of the cycloid type. They had annuli with a cyclic pattern, identified either as a discordance in the arrangement of the circuli or as a narrow space between adjacent circuli. The annuli were easily distinguishable in young individuals but, in old ones, growth mark counting was very difficult because the annuli were crowded near the scale margin that sometimes appeared eroded. Moreover, regenerated scales characterized by a large focus with no distinguishable growth marks were more numerous in old specimens.

The cross-sections of dorsal fin rays had chromophilic rings in the cortical region that were considered growth marks (Fig. 3). Indeed, these chromophilic rings corresponded to Arrested Growth Lines (AGL; also called "Lignes d'Arrêt de Croissance" or LAC in CASTANET *et al.,* 1992). The medullar part of the dorsal fin rays had often undergone an important resorption, forming cavities in the primary bone. In some cases, these cavities were occupied by new osseous tissue called secondary bone that had no growth marks (Fig. 4). Thus, the remodeling process destroyed a variable number of rings and the age of individuals was underestimated.

Otolith cross-sections, observed under dark field incident light, had alternating black and white bands. The white bands were dense zones whereas the black bands were translucent annuli

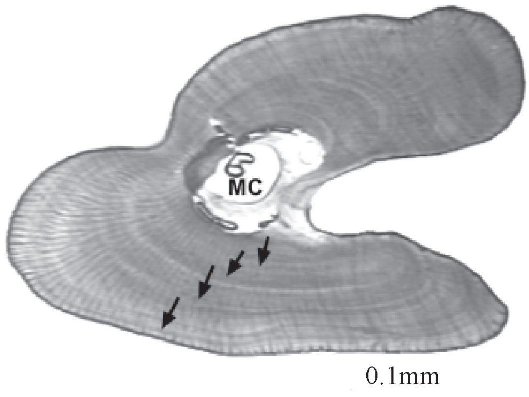

Fig. 3. Transversal section of a fin ray, observed under a microscope with natural transmitted light, showing four annuli (arrows) in a specimen of 17 cm fork length. MC = medullar cavity

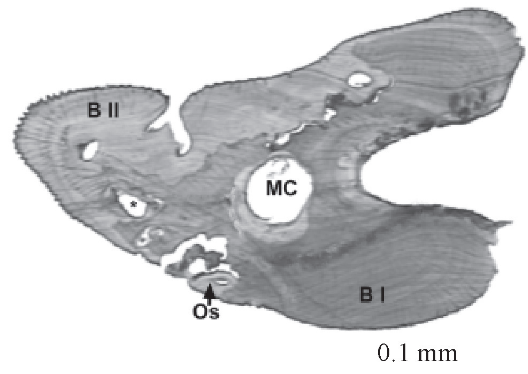

Fig. 4. Transversal section of a fin ray observed using a microscope with natural transmitted light. In this specimen of 17 cm fork length, resorption processes are responsible for the presence of cavities in the primary bone (B I) where the early growth marks were destroyed. Some cavities were filled with newly-formed secondary bone (B II), organized in osteon (Os). MC = medullar cavity

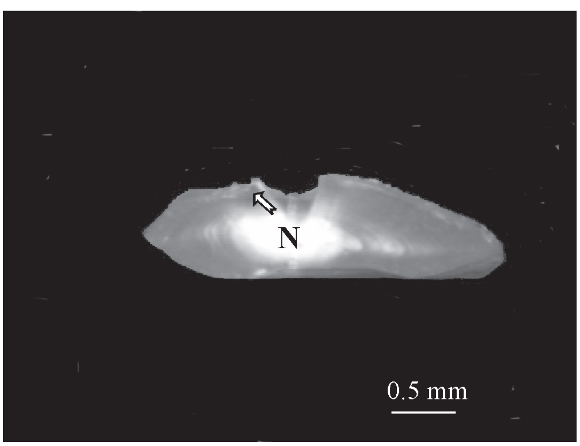

Fig. 5. Section of an otolith of a young specimen, observed using a binocular with dark field incident light. The false ring is a secondary growth structure (white arrow) and is probably related to development events. N: nucleus. Specimen of 7.6 cm fork length

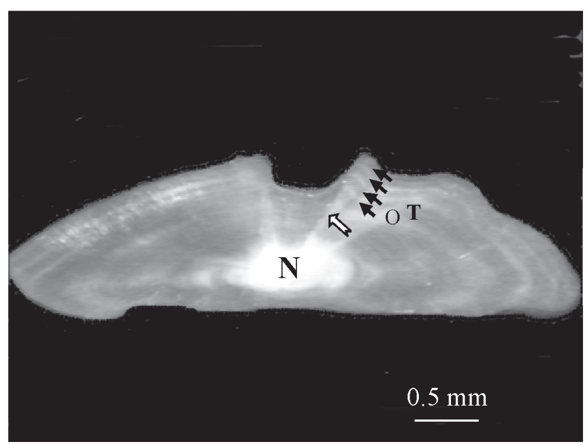

Fig. 6. Section of an otolith observed using a binocular with dark field incident light. Four annuli are observed (arrows). The opaque zone appears as a clear layer (O) and the translucent zone appears as a dark layer (T). N: nucleus. Specimen of 17.5 cm in fork length

(Figs. 5,6). The black and white bands were regularly arranged in the course of time. The thickness of the bands decreased in width from the nucleus to the edge, describing the growth curve. The obvious decrease of space separating the first and second hyaline zones reflected the onset of the first spawning. In most cases the pattern of growth marks was clear and legible and counting the growth increments was quite easy, even in old specimens.

The reliability of the age estimates made by reading the growth marks of the various skeletal elements was tested for 30 individuals. The highest APE (20.2%) was found in the scales, reflecting the difficulty in distinguishing growth marks on the scale edges. Otoliths had the lowest

APE (6.3%) reflecting good concordance in the readings. Fin rays had an APE of 8.5%.

The WILCOXON test revealed a significant discrepancy between the ages estimated using otolith sections and those estimated using fin rays (W = 4.52<1.96). This discrepancy was related to intense remodeling in the fin rays that destroyed the earliest rings, leading to underestimation of age. Significant differences were also observed between the ages estimated by reading sections of fin rays and scales (W = 8.62>1.96) and between scales and cross-sectioned otoliths (W = 2.64>1.96). Ages estimated using the scales tended to be much lower than those estimated using the otoliths.

Age and growth

Marginal zone analysis showed that the relative marginal distance (RMD) dropped in November and stayed low until April (Fig. 7). During this period higher percentages of otoliths with hyaline marginal zones were observed. From May, the RMD increased, reaching a peak in July, and then decreased until October. Only one clearly defined peak was observed during the annual cycle, therefore one hyaline zone was deposited per year. This took place between November and April. The opaque zone was formed during late spring and summer.

The distributions of length frequency at different ages of specimens from different areas are shown in Tables 1-4. A large length range was recorded for each age group, particularly in the G0-3 age groups. In all areas, the fishery seemed supported mainly by the four youngest age groups. In the north, the G0 age group was missing whereas in the Gulf of Tunis and the south, specimens older than 7 years were not observed.

The age and length data were fitted into the Von BERTALANFFY growth model. The equations obtained for each area were: for the north $L_F = 28.67\ (1 - \exp(-0.2\ (t + 1.41))$, $R^2 = 0.90$, no. = 223; for the Gulf of Tunis $L_F = 24.27\ (1 - \exp(-0.23(t + 1.65))$, $R^2 = 0.90$, no. = 230; for the east $L_F = 26.73\ (1 - \exp(-0.22(t + 1.43))$, $R^2 = 0.97$, no. = 298; and for the south $L_F = 23.48\ (1 - \exp(-0.21(t + 1.98))$, $R^2 = 0.92$, no. = 253 where $L_F =$ fork length (cm), t = age (years), R^2 = regression coefficient, and no. = number of specimens. In all areas, the length increased more quickly during the first four

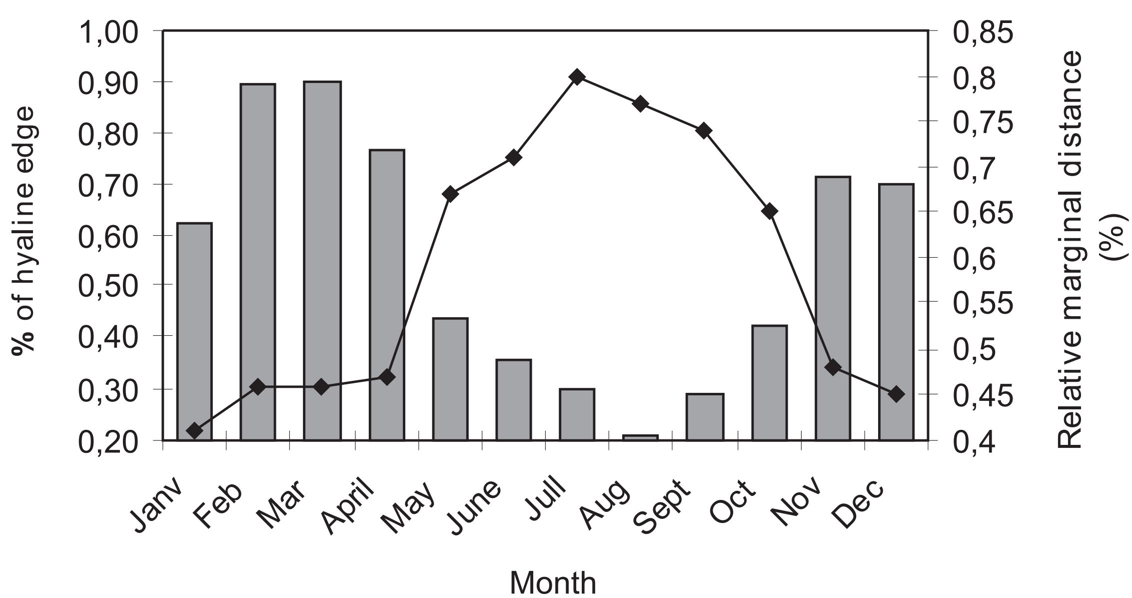

Fig. 7. Monthly evolution of the Relative Marginal Distance (curve) and percentage of marginal hyaline zone (bars)

Table 1. Length frequency distribution of bogues of different ages in the northern area (G = age group)

	Age group								
Length (cm)	G1	G2	G3	G4	G5	G6	G7	G8	G9
11-11.5	1	-	-	-	-	-	-	-	-
11.5-12	4	-	-	-	-	-	-	-	-
12-12.5	10	-	-	-	-	-	-	-	-
12.5-13	5	-	-	-	-	-	-	-	-
13-13.5	5	-	-	-	-	-	-	-	-
13.5-14	3	5	-	-	-	-	-	-	-
14-14.5	4	11	-	-	-	-	-	-	-
14.5-15	1	9	-	-	-	-	-	-	-
15-15.5	-	18	-	-	-	-	-	-	-
15.5-16	-	14	2	-	-	-	-	-	-
16-16,5	-	9	7	-	-	-	-	-	-
16,5-17	-	2	11	-	-	-	-	-	-
17-17,5	-	-	8	-	-	-	-	-	-
17,5-18	-	-	6	5	-	-	-	-	-
18-18,5	-	-	7	2	-	-	-	-	-
18,5-19	-	-	2	6	-	-	-	-	-
19-19,5	-	-	-	10	-	-	-	-	-
19,5-20	-	-	-	9	3	-	-	-	-
20-20,5	-	-	-	-	11	-	-	-	-
20,5-21	-	-	-	-	6	-	-	-	-
21-21,5	-	-	-	-	3	3	-	-	-
21,5-22	-	-	-	-	1	4	-	-	-
22-22,5	-	-	-	-	1	3	-	-	-
22,5-23	-	-	-	-	-	1	2	-	-
23-23,5	-	-	-	-	-	2	2	3	-
23,5-24	-	-	-	-	-	-	-	1	-
24-24,5	-	-	-	-	-	-	-	-	-
24,5-25	-	-	-	-	-	-	-	-	1
Total	33	68	43	32	25	13	4	4	1

Table 2. Length frequency distribution of bogues of different ages in the Gulf of Tunis (G = age group)

	Age group							
Length (cm)	G0	G1	G2	G3	G4	G5	G6	G7
9-9.5	2	-	-	-	-	-	-	-
9.5-10	1	-	-	-	-	-	-	-
10-10.5	2	-	-	-	-	-	-	-
10.5-11	3	8	-	-	-	-	-	-
11-11.5	-	5	-	-	-	-	-	-
11.5-12	-	9	-	-	-	-	-	-
12-12.5	-	4	-	-	-	-	-	-
12.5-13	-	4	-	-	-	-	-	-
13-13.5	-	7	8	-	-	-	-	-
13.5-14	-	1	19	-	-	-	-	-
14-14.5	-	-	21	-	-	-	-	-
14.5-15	-	-	11	-	-	-	-	-
15-15.5	-	-	12	1	-	-	-	-
15.5-16	-	-	7	10	-	-	-	-
16-16,5	-	-	2	8	-	-	-	-
16,5-17	-	-	-	12	-	-	-	-
17-17,5	-	-	-	11	-	-	-	-
17,5-18	-	-	-	10	5	-	-	-
18-18,5	-	-	-	5	4	-	-	-
18,5-19	-	-	-	3	8	3	-	-
19-19,5	-	-	-	-	5	5	-	-
19,5-20	-	-	-	-	-	3	3	-
20-20,5	-	-	-	-	-	-	5	-
20,5-21	-	-	-	-	-	-	-	1
21-21,5	-	-	-	-	-	-	-	1
21,5-22	-	-	-	-	-	-	-	1
Total	8	38	80	60	22	11	8	3

Table 3. Length frequency distribution of bogues of different ages in the eastern area (G = age group)

	Age group											
Length (cm)	G0	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G13
6-6,5	1	-	-	-	-	-	-	-	-	-	-	-
6,5-7	2	-	-	-	-	-	-	-	-	-	-	-
7-7,5	4	-	-	-	-	-	-	-	-	-	-	-
7,5-8	3	-	-	-	-	-	-	-	-	-	-	-
8-8,5	1	-	-	-	-	-	-	-	-	-	-	-
8,5-9	1	-	-	-	-	-	-	-	-	-	-	-
9-9,5	1	-	-	-	-	-	-	-	-	-	-	-
9,5-10	-	-	-	-	-	-	-	-	-	-	-	-
10-10.5	1	1	-	-	-	-	-	-	-	-	-	-
10.5-11	-	1	-	-	-	-	-	-	-	-	-	-
11-11.5	-	10	-	-	-	-	-	-	-	-	-	-
11.5-12	-	6	-	-	-	-	-	-	-	-	-	-
12-12.5	-	9	-	-	-	-	-	-	-	-	-	-
12.5-13	-	11	-	-	-	-	-	-	-	-	-	-
13-13.5	-	9	-	-	-	-	-	-	-	-	-	-
13.5-14	-	4	14	-	-	-	-	-	-	-	-	-
14-14.5	-	-	22	-	-	-	-	-	-	-	-	-
14.5-15	-	-	18	-	-	-	-	-	-	-	-	-
15-15.5	-	-	20	-	-	-	-	-	-	-	-	-
15.5-16	-	-	10	3	-	-	-	-	-	-	-	-
16-16,5	-	-	13	11	-	-	-	-	-	-	-	-
16,5-17	-	-	-	16	-	-	-	-	-	-	-	-
17-17,5	-	-	-	19	-	-	-	-	-	-	-	-
17,5-18	-	-	-	9	7	-	-	-	-	-	-	-
18-18,5	-	-	-	2	12	-	-	-	-	-	-	-
18,5-19	-	-	-	-	11	1	-	-	-	-	-	-
19-19,5	-	-	-	-	8	5	-	-	-	-	-	-
19,5-20	-	-	-	-	-	6	-	-	-	-	-	-
20-20,5	-	-	-	-	-	4	-	-	-	-	-	-
20,5-21	-	-	-	-	-	4	3	-	-	-	-	-
21-21,5	-	-	-	-	-	-	3	-	-	-	-	-
21,5-22	-	-	-	-	-	-	1	-	-	-	-	-
22-22,5	-	-	-	-	-	-	-	2	1	-	-	-
22,5-23	-	-	-	-	-	-	-	1	-	-	-	-
23-23,5	-	-	-	-	-	-	-	-	1	-	-	-
23,5-24	-	-	-	-	-	-	-	-	1	1	-	-
24-24,5	-	-	-	-	-	-	-	-	-	-	-	-
24,5-25	-	-	-	-	-	-	-	-	-	2	-	-
25-25,5	-	-	-	-	-	-	-	-	-	-	-	-
25,5-26	-	-	-	-	-	-	-	-	-	-	1	-
32-32,5	-	-	-	-	-	-	-	-	-	-	-	1
Total	14	51	97	60	38	20	7	3	3	3	1	1

Table 4. Length frequency distribution of bogues of different ages in the southern area (G = age group)

	Age group							
Length (cm)	G0	G1	G2	G3	G4	G5	G6	G7
7,5-8	2	-	-	-	-	-	-	-
8-8,5	5	-	-	-	-	-	-	-
8,5-9	3	-	-	-	-	-	-	-
9-9.5	6	-	-	-	-	-	-	-
9.5-10	7	-	-	-	-	-	-	-
10-10.5	3	6	-	-	-	-	-	-
10.5-11	8	18	-	-	-	-	-	-
11-11.5	3	20	-	-	-	-	-	-
11.5-12	-	15	-	-	-	-	-	-
12-12.5	-	14	2	-	-	-	-	-
12.5-13	-	5	8	-	-	-	-	-
13-13.5	-	-	16	-	-	-	-	-
13.5-14	-	-	15	-	-	-	-	-
14-14.5	-	-	15	2	-	-	-	-
14.5-15	-	-	10	4	-	-	-	-
15-15.5	-	-	6	11	-	-	-	-
15.5-16	-	-	2	6	1	-	-	-
16-16,5	-	-	-	7	-	-	-	-
16,5-17	-	-	-	5	7	-	-	-
17-17,5	-	-	-	2	4	-	-	-
17,5-18	-	-	-	-	4	-	-	-
18-18,5	-	-	-	-	3	2	-	-
18,5-19	-	-	-	-	-	1	-	-
19-19,5	-	-	-	-	-	1	1	-
19,5-20	-	-	-	-	-	1	1	-
20-20,5	-	-	-	-	-	-	-	1
Total	37	78	74	37	19	5	2	1

years than later on. Indeed, in all areas, the growth rate was about 18% during the first year and only 5% in the fifth.

Significant differences in length were observed in all age groups between all areas, except for age group 1 between the north and east and age groups 1 and 7 between the Gulf of Tunis and the south (Tables 5-7). Despite this, two groups of growth curves emerged (Fig. 8). In the north and east, L_∞ was greater than 26 cm whereas in the Gulf of Tunis and the south, L_∞ was about 24 cm.

Table 5. Results of the t test comparing length(cm) in age groups 1-7 between the northern area and the Gulf of Tunis and eastern areas

	North		Gulf of Tunis		*t*	North		East		*t*
Age	L_F±SD	No.	L_F±SD	No.		L_F±SD	No.	L_F±SD	No.	
1	12.58±1.02	33	11.82±0.97	38	3.15*	12.58±1.02	33	12.26±0.84	51	1.71
2	15.03±0.86	68	14.49±0.84	80	3.75*	15.03±0.86	68	14.78±0.73	97	2.48*
3	17.08±0.7	43	16.6±0.69	60	3.65*	17.08±0.7	43	16.83±0.53	60	2.28*
4	19.02±0.59	32	18.2±0.41	22	6.34*	19.02±0.59	32	18.45±0.55	38	4.54*
5	20.4±0.6	25	19.02±0.3	11	6.61*	20.4±0.6	25	19.73±0.64	20	3.43*
6	21.86±0.76	13	19.9±0.20	8	6.61*	21.86±0.76	13	20.88±0.39	7	3.16*
7	22.58±0.25	4	21.03±0.59	3	6.05*	22.58±0	4	22.16±0.28	3	3.48*

* significantly different t = value of *t* test
SD = standard deviation No. = number of specimens

Table 6. Results of the t test comparing length (cm) in age groups 1 to 7 between the Gulf of Tunis and the eastern and southern areas

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	Gulf of Tunis		East		*t*	Gulf of Tunis		South		*t*
Age	L_F±SD	No.	L_F±SD	No.		L_F±SD	No.	L_F±SD	No.	
1	11.82±0.97	38	12.26±0.84	51	2.44*	11.82±0.97	38	11.58±0.79	78	1.78
2	14.49±0.84	80	14.78±0.73	97	2.53*	14.49±0.84	80	13.90±0.97	74	3.85*
3	16.6±0.69	60	16.83±0.53	60	2.03*	16.6±0.69	60	15.75±0.95	37	5.21*
4	18.2±0.41	22	18.45±0.55	38	2.11*	18.2±0.41	22	17.03±0.66	19	7.41*
5	19.02±0.3	11	19.73±0.64	20	3.13*	19.02±0.3	11	18.68±0.75	5	1.43*
6	19.9±0.20	8	20.88±0.39	7	5.81*	19.9±0.20	8	19.3±0.49	2	2.55*
7	21.03±0.59	3	22.16±0.28	3	3.15*	21.03±0.59	3	20±0	1	1.62

* significantly different t = value of *t* test
SD = standard deviation No. = number of specimens

Table 7. Results of the t test comparing length (cm) in age groups 1 to 7 between the southern area and the northern and eastern areas

	South		North		*t*	South		East		*t*
Age	L_F±SD	No.	L_F±SD	No.		L_F±SD	No.	L_F±SD	No.	
1	11.58±0.79	78	12.58±1.02	33	5.77*	11.58±0.79	78	12.26±0.84	51	5.43*
2	13.90±0.97	74	15.03±0.86	68	7.07*	13.90±0.97	74	14.78±0.73	97	6.99*
3	15.75±0.95	37	17.08±0.7	43	7.71*	15.75±0.95	37	16.83±0.53	60	7.51*
4	17.03±0.66	19	19.02±0.59	32	10.49*	17.03±0.66	19	18.45±0.55	38	8.17*
5	18.68±0.75	5	20.4±0.6	25	5.49*	18.68±0.75	5	19.73±0.64	20	3.18*
6	19.3±0.49	2	21.86±0.76	13	4.49*	19.3±0.49	2	20.88±0.39	7	4.63*
7	20±0	1	23.0±0	4	10.29*	20±0	1	22.16±0.28	3	6.5*

* significantly different
t = value of *t* test
SD = standard deviation
No. = number of specimens

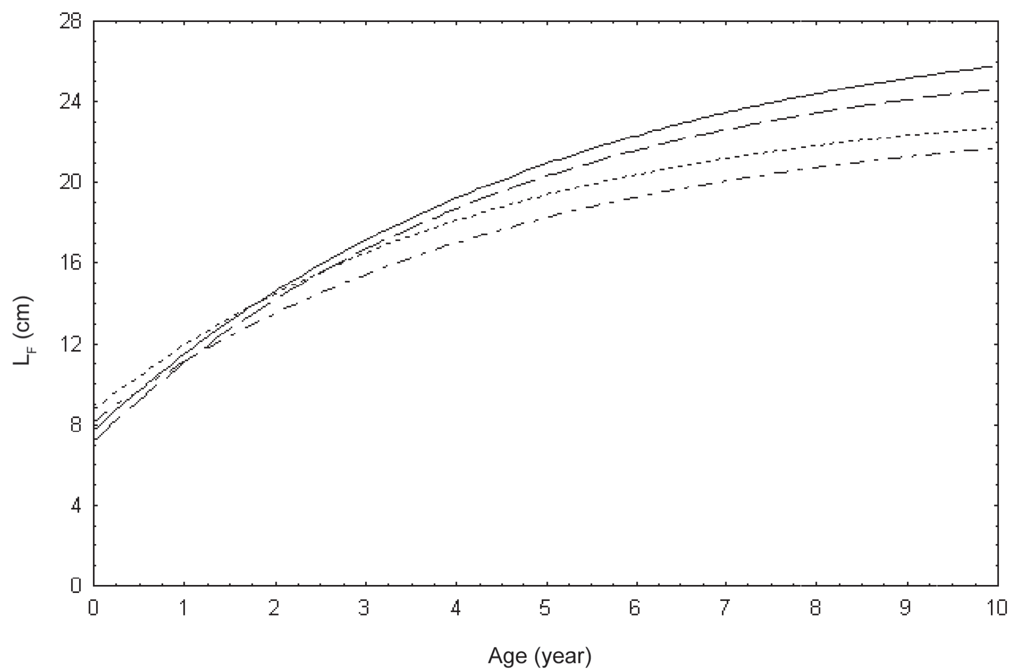

Fig. 8. Growth curves fitted to the length age data for bogue in the north (———), Gulf of Tunis (— —), east (— — —), and south (— · —)

DISCUSSION

The first step in estimating bogue age was to determine which skeletal structure was most reliable and the most accurate method of preparing this structure. Our choice was based on legibility, distinctiveness, and regularity of the growth marks. Because of intense remodeling that destroyed much of the growth marks, the opercular bone was immediately rejected. The vertebrae were also rejected because of numerous minute marks unrelated to cyclic events, as was reported for the Pacific blue marlin *Makaira nigricans* (HILL *et al.*, 1989) and the flatfish *Kareius bicoloratus* (KUSAKARI, 1969).

Fin rays, scales, and otoliths with cyclic growth marks were evaluated as skeletal structures that could be used to determine age (PANFILI *et al.*, 2002). In most cases, fin rays had undergone strong medullar remodeling that destroyed the earliest growth marks, leading to underestimation of age. According to CASTANET *et al.* (1992), bone integrity is essential for age estimation studies. Scales were easy to collect and process, but the growth marks in old specimens were very close to the edge and almost indistinguishable, as reported for bogue from the Gulf of Lion (GIRARDIN & QUIGNARD, 1986). This complication is illustrated by the high APE value. As found in this study, scale examination led to underestimation of age in old specimens of ocean perch *Helicolenus percoides* (WITHELL & WANKOWSKI, 1988) and rainbow darter *Etheostoma caeruleum* (BECKMAN, 2002). Bogue, similar to other teleosts, lose scales during life and regenerated scales are numerous, especially in old specimens. The superficial ornamentation of regenerated scales differs from that of original scales (BEREITER-HAHN & ZYLBERBERG, 1993); regenerated scales do not have annuli in the large focus.

Although time-consuming, examination of otolith cross-sections was the most informative method of aging because otoliths are not subject to the mineral resorption that occurs in bones (SIMKISS, 1974; PANFILI *et al.*, 2002). The agreement among estimates also supported the use of cross-sectioned otoliths for aging. Consequently, otolithometry was retained in the present study to continue the study of age and growth in bogue.

Otoliths had a ring pattern, similar to other teleosts. Concentric growth marks were composed of an opaque zone and a hyaline zone. The hyaline zone was formed yearly from November to April. The formation of one annulus per year is similar to that reported by GIRARDIN & QUIGNARD (1986) in the Gulf of Lion. The formation of the hyaline zone in autumn and winter supports the hypothesis that the hyaline zone corresponds to a reduction in the growth rate. Thus, formation of the hyaline zone could be a response to a fall in temperature or changes in other environmental variables such as food availability. It could be also due to reproduction, since bogue mature during the same period that annuli are formed.

In all four areas, growth was relatively fast during the first four years of life and then the growth rate fell. The decrease in growth was seen in the otoliths as a decrease in width of the spaces separating the annuli. The obvious tightening observed in the growth marks after the first hyaline zone could be attributed to the attainment of first maturity, which takes place at age 13-15 months (unpubl. results). The observed longevity of Tunisian bogue differed from one area to another; the longest was recorded in the east (13 years) and north (9 years), whereas longevity in the Gulf of Tunis and the south did not exceed 7 years.

The maximum size of our samples was 32 cm and this specimen was also the oldest: 13 years. This longevity is greater than those reported in other studies, expect for the Adriatic Sea by ALEGRÍA HERNANDEZ (1989) who estimated 16.6 years using TAYLOR's concept. This could be related to the method of preparing the structure used for age estimation. Indeed, many studies examined the otolith *in toto*; however it is well known that otoliths in old specimens thicken. GORDO (1996) reported that age determination by direct observation of otoliths presents difficulties as age increases. Using this method, some age information is inaccessible, which may lead to underestimation of age.

In the east, the L_∞ was much lower than the actual size observed there, i.e., 32 cm. This could be due to the fact that samples from near the shore were pooled with those from the open sea or because our samples consisted of individuals with slow growth. Either could explain the difficulty in fixing a realistic L_∞.

Growth patterns in the north and east were comparable to that on the Castellan coast while growth patterns in the Gulf of Tunis and the south were comparable to those of the Gulf of Lion and the Adriatic Sea until the fourth year (Table 8). Afterward, growth on the Tunisian coast became slower, although it exceeded growth of bogue in the Toscanian Sea. Bogue had higher growth potential in Lebanon and the Gulf of Cadiz than on the Tunisian coast. Are these growth differences related to differences in environmental conditions or biotic factors or

Table 8. Mean fork length (cm) versus age in bogue from various regions

	North	Gulf of Tunis	East	South	Gulf of Lion		Toscanian Sea	Adriatic Sea	Castellan coast	Portuguese waters	Lebanese waters
Age (year)	Otoliths[1]	Otoliths[1]	Otoliths[1]	Otoliths[1]	Otoliths[2]	Scales[3]	Otoliths[4]	Otoliths[5]	Scales[6]	Otoliths[7]	Statistic[8]
1	12.0	11.07	11.5	10.9	10.6	8.2	12	-	12.7	15.15	12
2	15.0	13.7	14.5	13.5	12.9	12.6	13.3	13.26	15.5	18.2	16.5
3	17.8	16	17	15.5	15.3	15.4	14.2	15.77	17.8	20.62	19
4	19.9	17.7	19	17	17.6	18	15.9	18.02	19.7	23.13	-
5	21.6	19	20.5	18	20	19.8	17.7	19.83	21.4	25.46	-
6	23.05	20	22	19.2	22.3	21.4	18.5	21.4	-	27.61	-

[1] This study
[2] ROMESTAND (1978)
[3] GIRARDIN AND QUIGNARD (1986)
[4] MATTA (1958)
[5] ALEGRÍA HERNANDEZ (1989)
[6] ZUNIGA (1967)
[7] GORDO (1996)
[8] MOUNEIME (1978)

did they result from the use of different methods for determining age or different procedures of fitting data into the Von BERTALANFFY growth equation?

To overcome differences related to sample preparation, the methods of determining age and fitting data to the Von BERTALANFFY growth equation were the same for all areas in this study. In this way, our results favored the influence of environmental and/or biotic factors. Although significant differences in growth were observed among all areas, the north seemed to be related to the east and the Gulf of Tunis to the south. Thus, two pools were distinguished: the first had a higher L_∞ value than the second.

Specimens from the open sea were larger than those from the coast. The geographic distribution by mean total length showed that the largest specimens were located at depths of 50-100 m, while the youngest were located on the bottom near the coast (BEN ABDALLAH *et al.,* 2004). Mean length tended to increase with depth, consistent with the bigger deeper concept (HEINCKE, 1913 *in* ALLAIN, 1999) that states that larger fish are usually associated with deeper waters. Several environmental factors may be behind these growth differences, the most likely being temperature. Fish are very sensitive to temperature changes and were reported to respond to a change of only 0.03°C (BULL, 1952). L_∞ has been shown to increase as temperature decreases (SINOVČIĆ, 2000; BASILONE *et al*., 2004). TAYLOR (1959 in SINOVČIĆ, 2000) found that an increase of just 1°C in mean annual temperature reduced L_∞ by 29 cm in the Atlantic cod *Gadus morhua*. Temperatures in the northern and eastern areas were lower than those in the southern area and shallow waters of the Gulf of Tunis (BRANDHORST, 1977). Consequently, fish in the north and east had a lower metabolism, which is associated with a longer life span and greater mean length. The greater length allowed the fish to migrate towards feeding areas and to store energy reserves. Conversely, in the Gulf of Tunis and the south, relatively high temperatures tended to result in shorter lengths. Food could not be considered a limiting factor since the food supply in the Gulf of Tunis and the south are reported to be high (AZOUZ, 1974; HATTOUR *et al.,* 1995). Nevertheless, according to MERETT & MARSHALL (1981), an environment with greater food availability supports small fish since they need not accumulate energy reserves.

The influence of genetics factors on growth cannot be disregarded although, until now, genetic studies of bogue are lacking in all areas of its distribution. In other teleosts, similar differences in growth in small geographic areas (offshore/inshore) were reported for the Atlantic cod *G. morhua* in the Atlantic (IMSLAND & JONSDOTTIR, 2003) and the anchovy *Engraulis encrasicolus* in the Mediterranean Sea (BORSA, 2002). These authors emphasized the existence of two genetically different populations for each species, a coastal population with a small size and a pelagic population with a larger size. Differences in regime hydrology between regions are generally reported as a barrier to delineate populations. Along the Tunisian coast, heterogeneity between bogue populations on micro geographic scales may exist, but since no genetic studies have been conducted on this species it is difficult to draw firm conclusions, especially because high phenotypic variability in fish was assumed not necessarily to be related to high genetic variability (IHSSEN *et al.*, 1981).

CONCLUSIONS

Study of cross-sectioned otoliths of *Boops boops* from off the Tunisian coast shows that bogue grow rapidly during the first four years of life, after which growth slows. The oldest specimen was 13 years old and recorded in the eastern region. Comparison of length increases between the different areas suggests the existence of two growth patterns that seem to follow an offshore-inshore gradient. Fish growth can be influenced by biotic factors related to the genotype or physiological condition of the fish, by abiotic factors, or by a combination of the two. Nothing being known on this issue for bogue, clear conclusions cannot be made regarding the relative importance of environmental and genetic factors on the growth rate variability observed in this study. Further studies are needed to determine the origin of the growth differences and whether they are related only to environmental conditions or if a genetic basis may also be involved. Such data are of great importance for improving stock assessment, as rational stock management should be based on the population, subdivided according to phenotypic heterogeneity induced by environmental variability.

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Starost i rast bukve, Boops boops, u tuniskim vodama

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SAŽETAK

Određivani su rast i starost bukve (*Boops boops)* na četiri područja tuniske obale proučavanjem prstenova rasta na poprečnim presjecima otolita. Ova kalcificirana struktura bila je odabrana radi veće jasnoće i pravilnosti prstenova rasta nego na drugim skeletnim elementima. Škržni poklopci i žbice peraja nisu bili uzeti u obzir radi intezivnog koštanog preobličavanja, a vretenca radi brojnih znakova koji se ne odnose na cikličke pojave. Ljuske nisu bile pogodne jer je brojanje prstenova bilo vrlo neprimjereno, naročito kod starih primjeraka. Za ljuske je srednji postotak pogrešaka redovito bio najveći. Na rubnim dijelovima otolita bukve stvara se hialina zona svake godine od studenog do travnja. Prema Von BERTALANFFY-jevim jednadžbama određeni su porast dužine i odnos dužina-starost. Usporedbe dužinskog porasta ukazuju na veći porast primjeraka na sjeveru i istoku nego u Tuniskom zaljevu i na jugu. Odnosi između rasta i geografske raspodjele naznačili su važnost faktora sredine, naročito temperature i pristupačnosti hrane. Uloga genetskih i/ili epigenetskih faktora se također ne može isključiti.

Ključne riječi: *Boops boops*, tuniska obala, starost, rast, sklerokronologija, otoliti