

Growth of the dusky grouper *Epinephelus marginatus* (Linnaeus, 1758) (Teleostei, Serranidae), in the Natural Marine Reserve of Lavezzi Islands, Corsica, France*

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SUMMARY: The growth of *Epinephelus marginatus* living in the Natural Marine Reserve of the Lavezzi Islands was studied using the von Bertalanffy model. The growth parameters of this model were: $L_{\infty}=135.9$ cm, $K=0.08$, $t_0=-0.80$ years. The relationship between length and weight was $W=12.5 \cdot 10^{-2} TL^{2.60}$. Grouper lengths were similar in the Lavezzi Islands and in North Tunisia. The relative abundance of trophic resources in the Lavezzi Islands, due to a positive "reserve" effect and enhanced by a small population density of groupers, has great consequences on growth, compensating the effect of lower water temperature. A plausible explanation for the similarity between these two populations is that they belong to a single metapopulation.

Key words: Serranidae, *Epinephelus marginatus*, growth, Mediterranean Sea, marine reserve, Corsica.

INTRODUCTION

The distribution of the dusky grouper *Epinephelus marginatus* (ex *E. guaza*) (Linnaeus, 1758) extends from the English Channel (Wheeler *et al.*, 1975) to southern Africa (Smith *in* Tortonese, 1954) as well as the Mediterranean (Tortonese, 1954; 1967). The highest abundances are found in the African coast, from Tunisia to Senegal (Franqueville and Fréon 1976, Bruslé, 1985; Chauvet, 1991). Tortonese (1954) and Smith (1971) reported this species in the east coast of South America, but without certainty as based on the determination of only six individuals.

Epinephelus marginatus is often described as a territorial and sedentary fish, but Chauvet and Francour (1990), and Chauvet *et al.* (1991), show that sedentary phases alternate occasionally with wandering phases. Smith (1959), Atz (1964) and Bruslé and Bruslé (1975) described the presence of hermaphrodite protogynous sexuality in this species. These last authors place the sexual maturity at 5 kg and Chauvet (1988) at the age of 5 years. Sexual inversion occurs between 8 and 16 years in Tunisia (Chauvet, 1988). *E. marginatus* is currently being reclassified as a protected species in the Mediterranean and is listed in many red books as a threatened species (MNHN, 1987; Boudouresque *et al.*, 1991). In France, this endangered species is protected by the

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national decree of April 1993 and by Prefectorial orders concerning the control of spear fishing in French waters.

The growth of *E. marginatus* was studied in Tunisia by Rafail *et al.* (1969), Chauvet (1981, 1988) and Bouain (1984) and in Algeria by Kara and Djerbal (1995). The study of Rafail focused on 251 individuals, one to seven years old, caught from the Levantine Sea. Chauvet studied 107 individuals in 1981, completed by 163 individuals in 1988, aged from one to 36 years all captured by spear fishing in the North and North-East coasts of Tunisia. The study of Bouain focused on 109 individuals aged from one to 19 years sampled when landed in fishing harbours from the oriental coast of Tunisia. The study of Kara and Djerbal focused on 33 individuals captured in the Algerian east coast, aged from at least one to seven years as it was not possible to read scales beyond this age.

The present study of the growth of *E. marginatus* concerns specimens sampled in the Natural Marine Reserve of the Lavezzi Islands located to the south of Corsica in the Bouches de Bonifacio (Fig. 1). The results are compared to those provided in the five papers cited.

MATERIAL AND METHODS

The biological material studied is made up of scales collected during surveys of fish landed by fishermen between August 1990 and July 1993. Although age reading on otoliths was considered, it was not possible to remove the otoliths because the fishermen wished to keep the fish intact for sale. Scales were taken from between the lateral line and the dorsal fin. The sample includes 24 individuals from artisanal fishing undertaken in the Natural Marine Reserve in the Lavezzi Islands (Fig. 1).

Total length (TL in cm) and weight (W in g) of individuals were measured on board the fishing boat when scales were extracted. Two to ten scales were sampled on each grouper. Size and weight of the different individuals ranged between 20 and 120 cm, and between 0.7 and 24 kg respectively.

As it was not possible to validate the growth by independent means, for example the injection of tetracycline, the rhythm of the growth annuli observed on scales was determined by analogy to the previous works of Bouain (1984) and Chauvet

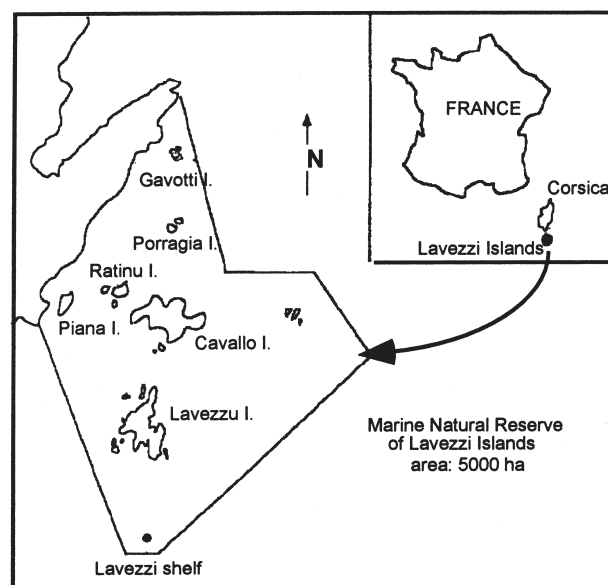


FIG. 1. – Geographical situation of the Natural Marine Reserve of the Lavezzi Islands.

(1988) and fixed to one year. The size of each fish was back calculated for all ages (Lee, 1920). Age determination and the measurement of distances from the center of the scale to the annuli (Fig. 2) were carried out under a microscope coupled to an image analysis system (Lam Hoai, 1992; Grill, 1989).

The mean length by age class was used to calculate the growth curve and determine the growth parameters of the von Bertalanffy model (1934). A maximum age was calculated with the relative increase $[(TL+1-TL)/TL]$. According to Chauvet (1988), after the age of 12 years, the relative increase of the body size decreases in a linear manner. He calculated the relationship between the relative linear increase and time ($dTL/TL=f(t)$), considering size values at ages of 12 years and more. This author obtained sizes of fish up to a maximum age at which the relative increase is null. The von Bertalanffy's parameters were calculated with a computer program written in BASIC by Lam Hoai (1989) using the Tomlinson and Abramson's method (1961) to study populations and ecosystems. According to Chauvet (1988), this method that minimizes the quadratic gaps, gives results influenced by the largest individuals of the sample. He preferred to use at that time Walford's method (1946) which minimizes the reduced quadratic gaps that attribute the same weight to all individuals of the sample.

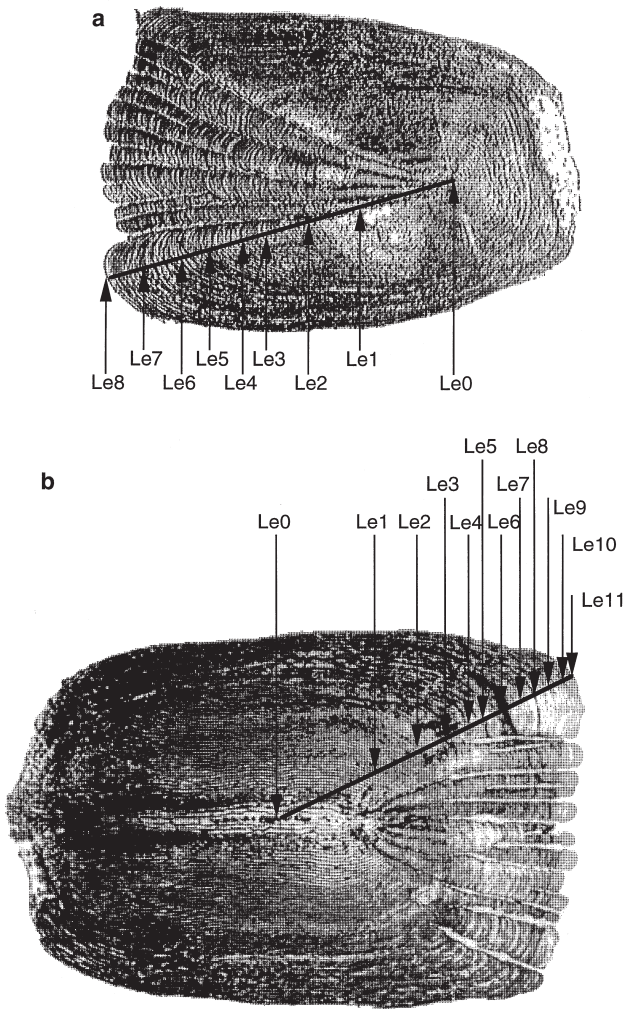


FIG. 2. – Measurements undertaken on two scales of 7mm (a) and 13mm (b) of two groupers *E. marginatus* respectively aged 8 years (TL = 60 cm) and 11 years (TL = 75 cm); Le0: center of the scale; Len: radius of the scale from 1 to n years.

The von Bertalanffy' relation is :

$$TL = L_{\infty} (1 - e^{-K(t - t_0)})$$

where: TL: total length; L_{∞} : asymptotic length; K: annual growth rate; t: age in years; t_0 : age at which TL=0.

The length - weight relationship was determined from size and weight measurements on 24 individuals using the equation:

$$W = aLT^b$$

where: W: weight in g; TL: total length in cm; a: coefficient related to the density and proportion of fish; b: allometry ratio.

Parameters a and b were obtained by a linear adjustment to the lesser rectangles realized on the logarithmic transformation of the equation.

RESULTS

We have no data on the age of two fishes because scales were unreadable.

The best relationship grouper size - scale size was the form: $y = axb$ and $\log y = b \log x + \log a$ when linearised.

After calculation: $\log TL = 0.695 \log Le + 2.418$, and the equation is: $TL = 261.82 \cdot Le^{0.695}$

with: TL: length of the fish (mm) and Le: radius of the scale (mm).

The correlation coefficient was $r = 0.648$; determination coefficient: $r^2 = 0.391$.

TABLE 1. – Mean values of the size (TL_{back} in cm) obtained by back-calculation at different ages (in years) for *E. marginatus*; n: number of fish specimens; n_{cum}: cumulated number; TL_{min}: minimum length; TL_{max}: maximum length; σ : standard deviation; dL: absolute increase; dL/L: relative increase (scales of two specimens were not readable).

age	n	n _{cum}	TL _{back}	TL _{min}	TL _{max}	σ	dL	dL/L
1	0	22	16.52	11.34	23.99	3.14	-	-
2	1	22	27.92	20.15	41.55	5.32	11.40	0.690
3	0	21	36.74	25.44	50.40	6.77	8.82	0.316
4	1	21	43.50	28.76	59.68	7.82	6.76	0.184
5	0	20	49.88	32.06	66.11	8.14	6.38	0.147
6	2	20	55.93	37.02	70.80	8.21	6.05	0.121
7	1	18	62.55	42.32	78.42	8.50	6.62	0.118
8	1	17	67.95	47.61	85.42	9.07	5.40	0.086
9	1	16	73.20	55.23	91.29	8.88	5.25	0.077
10	3	15	77.65	58.85	97.73	9.32	4.45	0.061
11	0	12	82.77	62.47	106.51	11.16	5.12	0.066
12	4	12	85.77	65.12	109.44	11.92	3.00	0.036
13	1	8	90.29	70.09	114.13	13.64	4.52	0.053
14	7	7	94.73	74.06	120.00	15.54	4.44	0.049

log a is supposed to represent the length of the fish when the scales appear, and helps normally to correct results of the back-calculation (Lee, 1920). Given the value found (2.418 mm) it is impossible to observe scales on a fish of such size, therefore the back-calculation has not been corrected. This can be explained by the absence of very small specimens.

TABLE 2. – Mean lengths TL (in cm) calculated from the adjustment of the linear increase according to the time, for age classes of *E. marginatus* from 15 to 26 years; absolute increase: $dL=TL+1-TL$; relative increase: dL/TL .

age	TL	dL	dL/TL
15	98.70	3.97	0.0419
16	102.47	3.77	0.0382
17	106.01	3.54	0.0345
18	109.28	3.27	0.0308
19	112.24	2.96	0.0271
20	114.87	2.63	0.0234
21	117.13	2.26	0.0197
22	119.00	1.87	0.0160
23	120.46	1.46	0.0123
24	121.50	1.04	0.0086
25	122.10	0.60	0.0049
26	122.25	0.15	0.0012

Linear growth and age estimation

Given the low sampling size, means of lengths have been obtained up to the age of 14 years (Table 1). From 14 to 26 years, mean lengths were calculated by using the extrapolation of the regression between relative increases of lengths and age (Table 2):

$$dL/L = -3.7 \cdot 10^{-3} t + 0.0974$$

Correlation coefficient: $r = -0.5044$.

The linear growth parameters of the von Bertalanffy model are presented in Table 3. Growth parameters of *Epinephelus marginatus* obtained in Lavezzi are not significantly different from those of Tunisia (Chauvet (1988) but differ from those obtained for this species in Egypt (Rafail *et al.*, 1969), south Tunisia (Bouain, 1984) and Algeria (Kara and Derbal, 1995) (Table 4). Growth curves (Fig. 3) show that the groupers from the Lavezzi Islands, at the same age as those from Tunisia, are of a slightly larger size.

TABLE 3. – Growth Parameters of the von Bertalanffy model for *E. marginatus* from the Lavezzi Islands; σ : standard deviation.

age class	L_{∞} (cm)	σ	K	σ	t_0	σ
1-14 years	135.91	19.23	0.0791	0.0207	-0.8032	0.4311
1-26 years	147.89	10.99	0.0695	0.0126	-0.8936	0.6058

TABLE 4. – Comparison of sizes of *E. marginatus* and growth parameters of the von Bertalanffy model (L_{∞} , K, t at age 0) from 5 different studies; Lavezzi: present work; North Tunisia: Chauvet (1988); Egypt: Rafail *et al.* (1969); South Tunisia: Bouain (1984); East Algeria: Kara and Derbal (1995); σ : standard deviation; t: Student's parameter for the comparison of values from the Lavezzi Islands and North Tunisia; ns: no significant difference; *: significant difference ($t < 0.05$).

age	Lavezzi TL	σ	N. Tunisia TL	σ	Student t	Egypt TL	S. Tunisia TL	E. Algeria TL
1	16.52	3.14	15.46	1.42	ns	17.06	11.79	19.74
2	27.92	5.32	24.83	2.75	*	23.59	16.38	28.52
3	36.74	6.77	34.33	2.86	ns	28.35	20.86	36.47
4	43.50	7.82	42.38	3.44	ns	34.80	25.23	39.97
5	49.88	8.14	46.91	4.53	ns	39.97	29.49	46.22
6	55.93	8.21	54.09	4.12	ns	43.96	33.65	53.05
7	62.55	8.50	60.06	4.91	ns	47.54	37.70	56.76
8	67.95	9.07	64.27	5.18	ns	-	41.65	-
9	73.20	8.88	68.66	5.00	ns	-	45.51	-
10	77.65	9.32	72.92	5.70	ns	-	49.27	-
11	82.77	11.16	76.83	6.32	ns	-	52.94	-
12	85.77	11.92	79.62	6.64	ns	-	56.51	-
13	90.29	13.64	82.47	7.42	ns	-	60.00	-
14	94.73	15.54	85.29	7.51	ns	-	63.40	-
L_{∞}	135.91		114.49			80.00	197.79	78.53
K	0.0791		0.0928			0.112	0.025	0.16
t_0	-0.803		-0.751			-1.086	-1.459	0.73

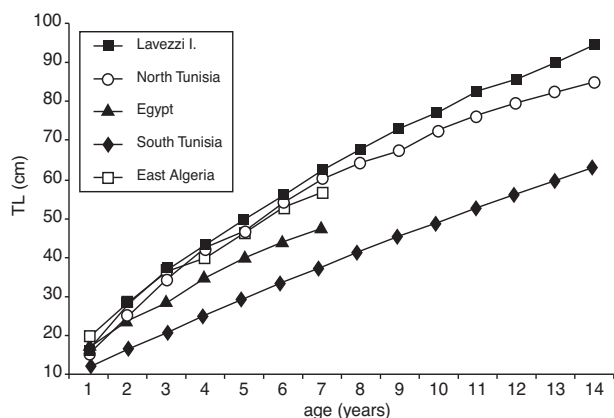


FIG. 3. – Linear growth comparison of *E. marginatus*; Egypt: Rafail *et al.* (1969); South Tunisia: Bouain (1984); North Tunisia: Chauvet (1988); East Algeria: Kara and Derbal (1995); Lavezzi Islands: present work.

Length - weight relationship

W: weight (g) and TL: length (cm)

Relationship $W = 0.125 TL^{2.60}$

Linearised expression $\ln W = 2.598 \ln TL - 2.079$

where: variance of $\ln W = 0.9592$; variance of $\ln TL = 0.1319$; covariance = 0.3375; correlation coefficient: $r = 0.9487$.

DISCUSSION

In the case of the growth equation obtained for 26 age classes, standard deviations of parameters L_{∞} and K of the von Bertalanffy equation are artificially diminished by the utilization of the regression, thus allowing the determination of the size of older fishes using relative linear increases. Hence, only data obtained for fishes up to 14 years are used for the discussion.

Linear growth

The growth of *Epinephelus marginatus* was similar at the Lavezzi Islands and in North Tunisia, whereas the value of the annual growth rate K found was lower. According to Laurec and Le Guen (1981), it is necessary to remember that growth parameters are just simple mathematical supports and have no value as biological characters *a priori* since they are sensitive to age classes that make up the sample and to the mathematical procedures used to obtain them. This last point most likely explains the difference of L_{∞} value as Chauvet's sampling (1988) included a larger number of small individuals.

The comparison of growth can be made with a test of comparison of means for size of each age class (Chauvet, 1988). This method has been used to compare results from Lavezzi to results from Tunisia (Table 4). The two series of mean lengths were not significantly different ($t > t_{0.05}$), except for at the age of two years. This difference could be due to the low number of individuals studied in Lavezzi. It could also be explained by a difference in the intensity of intra juvenile competition in the two sectors; the density of groupers in Tunisia being more important than in the Lavezzi Islands. However, if this were the case, a difference should also be observed for age class 1. Similarly, standard deviations per age class were about two times greater in our study as compared to that of Chauvet (1988), but show the same trends.

The mean water temperature difference between the regions could also explain the differences in size between the fish at each site. The Lavezzi Islands have a status of natural marine reserve. They comprise an ecosystem possessing a great species richness and an increasing fish density (Bouchereau *et al.*, 1989, 1992a, 1992b, 1997) as in the National Marine Park of Port-Cros (Francour and Harmelin, 1988). Marine bottoms around the Lavezzi Islands have an important trophic potential since they are covered by *Posidonia*. However, these seagrass beds offer few habitats to large fishes, as pointed out also by Derbal and Kara (1995) in the region of Annaba (Algeria). The groupers of this reserve are therefore over dispersed in rocky areas (Chauvet *et al.* 1991) without experiencing strong intra specific trophic competition. This would explain the good growth of *E. marginatus* in the Lavezzi Islands despite lower water temperatures (12°C to 25°C; Culioli, 1994) than in Tunisia (13°C to 27°C; Lemoalle *et al.*, 1984).

Chauvet (1988) used growth parameter for comparison of the Pauly's index (1979):

$$P = \log(W_{\infty} \times K),$$

with W_{∞} in g and K in year⁻¹.

This author found $P = 3.39$ from his data, $P = 3.50$ from Bouain's data (1984) and $P = 3.02$ from the data of Rafail *et al.* (1969). Pauly's index of the groupers from the Lavezzi Islands $P = 3.54$, agrees therefore with the index of the groupers from Tunisian coasts, which also differ from the index of Egyptian groupers.

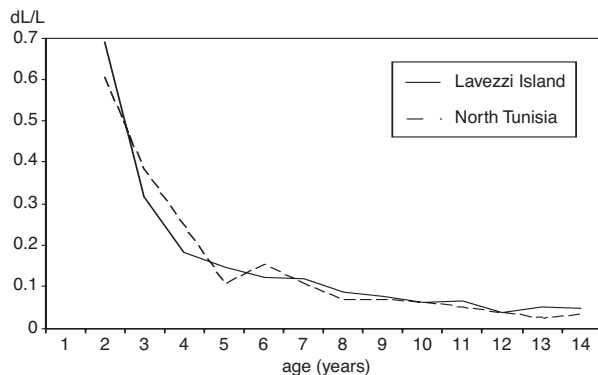


FIG. 4. – Annual evolution of the relative increase of the growth of *E. marginatus* from Tunisia (Chauvet, 1988) and the Lavezzi Islands (present work).

The homogeneity of growth of *E. marginatus* between Northern Tunisia and the Lavezzi Islands could reinforce the idea that these fishes are part of a single stock, as suggested by the study of the Grouper Study Group (G.E.M.: Groupe d'Etudes du Mérou; Anonymous, 1986 to 1994). The colonization of the northern parts of the Western Mediterranean basin should take place by the «process of advancement» from the South of the basin, especially the North African coasts (Chauvet *et al.*, 1991; Chauvet and Francour, 1990).

The curve of relative increases calculated from North Tunisian fishes (Chauvet, 1988) shows a significant decline when fish are five years old (Fig. 4) which is explained by a diversion of energy at first sexual maturity, to the profit of ovogenesis. The curve of relative increases for the grouper from the Lavezzi Islands shows a more regular shape. The abundance of trophic resources in the marine reserve might be the cause. Nevertheless, this point can also enhance the idea suggested by observations of the GEM (Anonymous 1986 to 1994) that spawnings take place exceptionnaly north of latitude 41°N. Over 20 years of observations (1974-1994) spawnings would not have taken place to the north of this latitude except in 1987, 1988 and 1989; observations reinforced by those of Camus *et al.* (1988), Bouchereau *et al.* (1989, 1992a, 1992b) and Tomasini *et al.* (1991). These last spawning events would explain the recent presence of small individuals (TL < 50 cm) in captures by fishermen in this sector (Tomasini *et al.* (1991).

The dusky grouper has significant longevity (Chauvet, 1988), and although the oldest fish present in our sample was only 19 years old (TL = 100 cm), older individuals have been found: 23 years for

Ancona (1937) and Bruslé and Prunus (1980), 24 years for Percier (1962), 36 years for Chauvet (1988), and Miraglia (1935) reported the death of a grouper in the aquarium of Napoli after 50 years in captivity.

Length - weight relationship

The exponent “b” of the relation $W = aTL^b$ here = 2.598 while the three other authors find a value significantly close to 3. This weak value is compensated in the adjustment by a coefficient “a” 10 times higher than those found by the other authors and underlines simply the small size of the sample.

Summary

Despite the small number of specimens of *E. marginatus* for this study (22 individuals), results are largely agree with those found by Chauvet (1988) based on 270 individuals from North Tunisia. The relative abundance of trophic resources in the Lavezzi Islands, due to the reserve status of the zone, emphasized by a low density of grouper population, would play a role in the growth by compensating the opposite effects, of the water temperature. However, the most plausible explanation to account for the convergence of results between these two studies would be that these populations belong to a same metapopulation.

A suitable genetic study on the populations as well as a study on classic ecobiological parameters would allow to better account for the population dynamics of the dusky grouper in the Western Mediterranean basin.

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