Journal of
Applied Ichthyology

J. Appl. Ichthyol. 27 (2011), 1254–1258

ISSN 0175–8659

Received: May 1, 2010
Accepted: September 15, 2010
doi: 10.1111/j.1439-0426.2011.01806.x

Age, growth and mortality of common two-banded seabream, *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817), in the eastern Adriatic Sea (Croatian coast)

By J. Dulčić[1], A. Pallaoro[1], S. Matić-Skoko[1], B. Dragičević[1], P. Tutman[1], R. Grgičević[1], N. Stagličić[1], V. Bukvić[2], J. Pavličević[3], B. Glamuzina[4] and M. Kraljević[1]

[1]*Institute of Oceanography and Fisheries, Split, Croatia;* [2]*Accomodation and Rehabilitation Centre, Metković, Croatia;* [3]*University of Mostar, Trg Htvatskih Velikana, Mostar, Bosnia and Herzegovina;* [4]*Department of Aquaculture, University of Dubrovnik, Ćire Cartića, Dubrovnik, Croatia*

Summary

Age, growth and mortality were analysed for the common two-banded seabream, *Diplodus vulgaris*, collected in the eastern Adriatic (Croatian coast) from commercial fishery catches by 'tramata' fishing (2005–2006) to obtain growth estimation. The oldest female was estimated to be age 11, the oldest male age 10 years. The von Bertalanffy growth parameters estimated by reading scales were: L_∞ = 48.60 cm (SE = 1.101), K = 0.112 (SE = 0.005) and t_0 = −2.366 (SE = 0.060) for all specimens; L_∞ = 51.96 cm (SE = 2.153), K = 0.095 (SE = 0.007) and t_0 = −2.837 (SE = 0.120) for females and L_∞ = 56.25 cm (SE = 2.662), K = 0.084 (SE = 0.067) and t_0 = −2.920 (SE = 0.117) for males. The overall sex ratio was 1.22 : 1 in favour of males. Total mortality, corresponding to the slope of the descending limb of the catch curve, was Z = 0.81 per year for females and Z = 0.85 per year for males. Exploitation ratios were E = 0.68 for females and E = 0.73 for males.

Introduction

The common two-banded sea bream, *Diplodus vulgaris* Geoffr., is a demersal species distributed throughout the Mediterranean and along the eastern Atlantic coast from France to Senegal, including the Madeira, the Azores and the Canaries Archipelago (Bauchot and Hureau, 1986). It can be found close to rocky and sand bottoms to a maximum depth of 160 m. It is common in the eastern Adriatic and is one of a highly valuable commercial species in Croatia (Jardas, 1996). In this region, sparids are subject to high commercial exploitation and constitute the main target family of small-scale fisheries (Jardas, 1996). According to some historical data, total landings of common two-banded sea bream in Croatia were around 15 tonnes per year (Grubišić, 1982).

The age, growth, mortality, sex ratio, spawning season, feeding, size at maturity and fisheries aspects of common two-banded sea bream have been studied thoroughly in various areas of its distribution (Rosecchi, 1987; Gordoa and Moli, 1997; Erzini et al., 1998; Gonçalves and Erzini, 2000; Gonçalves et al., 2003; Pajuelo and Lorenzo, 2003; Pajuelo et al., 2006; Abecasis et al., 2008). However, published information on its biology and ecology in the Adriatic Sea remain scarce. Pallaoro et al. (1994) presented data on feeding habits of juvenile stages of two-banded seabream in the eastern middle Adriatic, while Dulčić and Kraljević (1996a) reported parameters of its length-weight relationship. Dulčić et al. (1997) studied temporal fluctuations of abundance of common two-banded seabream juveniles in the National Park Kornati (eastern middle Adriatic). Studies on age, growth, mortality and exploitation rates, which are crucial for stock assessment of the common two-banded seabream, have not yet been undertaken in the eastern Adriatic.

The present paper deals with the growth, age and mortality of *D. vulgaris* to obtain growth estimation, which are important input parameters to stock assessment techniques and will provide an insight into the life history of this species.

Materials and methods

Specimens used in this study were obtained monthly from the 'tramata' fishing where *D. vulgaris* represents one of the target species along with other high priced sparid species (see Cetinić et al., 2002). Sampling took place in the eastern middle Adriatic, Croatian coast (Drvenik Island: 43°26′43″ N – 16°08′45″ E; Split: 43°30′34″ N – 16°26′48″ E; Hvar Island: 43°10′18″ N – 16°42′26″ E; Vis Island: 43°02′29″ N – 16°09′01″ E) from May 2005 to June 2006, and a total of 3729 specimens of *D. vulgaris* was examined for this study. Specimens were sampled from 'ludar', one of three kinds of tramata fishing. Ropes (up to 4000 m) are used for enclosing a large sea area (up to 4 km^2, but because of coastal and bottom configuration, mainly up to 1.5 km^2), herding fish by vibrations produced by the pulling of ropes, close to the coast; they are then harvested by common gillnet, the stretched mesh size of which must not be smaller than 56 mm. CPUE is around 288 individuals or 51.047 kg in one haul (average specimen: 180 g) (number representation 4.27%, weight representation 5.87%, immature specimens 31.93%) (Cetinić et al., 2002).

Age and growth were examined separately for males, females, and sexes combined, including immature specimens (for the total area). In all, 3729 fish were measured for total length (TL) to the nearest millimeter and weighed to the nearest gram. All specimens were sexed as male, female or immature based on macroscopic observation of the gonads. Age was determined by reading of the scale rings under a stereomicroscope at 100× magnification. Scales were removed (20–30 per specimen) from the left side of the fish, just under the lateral line and below the pectoral fin, and cleaned in 5% sodium peroxide. Each scale was read three times by three different readers using a compound microscope (magnification 1.6 × 11.2) with a black background and under reflected light. Only coincident readings of 93% individuals were accepted. The index of average percent error (IAPE) (Beamish and Fournier, 1981) as

U.S. Copyright Clearance Centre Code Statement: 0175–8659/2011/2705–1254$15.00/0

well as the mean coefficient of variation (CV) (Chang, 1982) were calculated to estimate the relative precision between readings. Low values of the indices indicated a good precision of age estimation. Ages were assigned based on techniques and validation proposed by Abecasis et al. (2008). The counts were converted into ages assuming 1 January as the designated day of birth (Williams and Bedford, 1974).

Length-weight relationship was calculated by applying the exponential regression $W = aL^b$, where W is the fish weight (g) and L the total length (TL) (cm). Growth type (isometric and allometric) was determined by the Student's t-test ($P < 0.05$).

For estimation of growth, the mean lengths of individuals assigned to each age group were used to fit the von Bertalanffy growth model applying the FISAT program package (Gayanilo et al., 1994).

Estimates of instantaneous total mortality (Z) were obtained using the linearized length-converted catch curve (Pauly, 1984). Natural mortality (M) was estimated using the general regression equation of Pauly (1980) with an annual mean water temperature value of 15.6°C. The instantaneous rate of fishing mortality (F) was estimated from the difference between Z and M. The exploitation rate (E) was determined according to Gulland (1971): $E = F/Z$.

Results

The common two-banded seabream specimens caught in the middle Adriatic (Croatian coast) ranged from 10.6 to 37.5 cm TL (mean 20.7 ± 4.23) and from 19.0 to 797.0 g (mean 152.0 ± 104.64). Females ranged from 14.5 to 37.5 cm (mean 21.8 ± 3.93) and from 43 to 797 g (mean 173.6 ± 107.49); males from 14.5 to 36.2 cm (mean 21.4 ± 3.88) and from 46 to 760 g (mean 163 ± 102.67). The gonads were macroscopically examined mainly during the maturity and spawning season. The mean size at first sexual maturity was 19.1 cm TL for females and 18.5 cm TL for males. All specimens sampled were fully mature above 22.0 cm TL (Fig. 1).

The length-weight relationship was calculated to include both sexes, $W = 0.0122\ TL^{3.068}$, and separately for females $W = 0.0126\ TL^{3.059}$ and for males $W = 0.0126\ TL^{3.055}$. The slope b was not significantly different from 3.0 (t-test, $P > 0.05$) (in all cases), indicating isometric growth.

Results on age determination by reading the scale rings are given in Table 1; 93% of the scales were readable (1620 males; 1333 females) for the study of age and growth. The index of

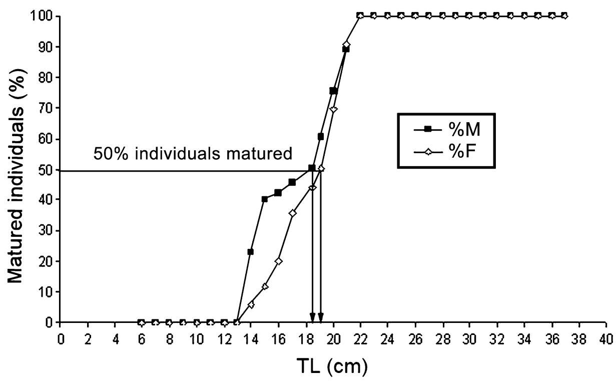

Fig. 1. Sexual maturity ogive for *Diplodus vulgaris* as a function of size (eastern middle Adriatic, 2005–2006)

Table 1
Mean total length (TL) for male, female and immature *Diplodus vulgaris* at different ages

	Males			Females			Immature		
Age	TL (cm)	±SD	N	TL (cm)	±SD	N	TL (cm)	±SD	N
1	16.22	0.740	180	15.98	0.895	146	14.73	1.563	345
2	18.49	0.898	481	19.05	0.845	363	17.77	0.732	170
3	21.94	1.261	595	21.95	1.329	481			
4	25.04	0.940	186	24.99	1.082	186			
5	27.24	1.013	100	27.45	0.972	80			
6	29.40	1.084	22	29.57	0.826	27			
7	31.05	1.005	42	31.20	1.095	39			
8	33.92	0.535	10	33.50	0.790	6			
9	34.57	0.503	3	34.63	0.231	3			
10	36.2	–	1	35.4	–	1			
11				37.5	–	1			
Total	1620			1333			515		

SD, standard deviation; N, number of specimens.

average percent error (IAPE) of ring counts for each reader did not differ greatly, and was slightly lower for the first author (2.13) than for the second (2.41) and third (2.83). The precision of the age estimates (CV) was 1.2. In general, scales were easy to read, with clearly identifiable increments, although the phenomenon of stacking of growth zone towards the scale edge, especially in fish older than 8 years, was evident. Scales showed clearly the ring pattern common to teleost fishes. The opaque zone was created during the summer months and was well presented on the scale margin during autumn.

The common two-banded seabream is a relatively long-lived species in the Adriatic Sea; the oldest female was estimated to be 11 years of age and the oldest male 10 years of age. Three-year-old individuals ranging in lengths from 18.9 to 25.6 cm TL (36.4%) dominated the sample. We estimated the von Bertalanffy growth parameters for the combined sample: $L_\infty = 48.60$ cm (SE = 1.101), $K = 0.112$ (SE = 0.005) and $t_0 = -2.366$ (SE = 0.060) ($R^2 = 0.953$). The non-linear least squares estimated parameters are given in Table 2. The calculated asymptotic length values agree well with the maximum observed length. The Von Bertalanffy Growth Function (VBGF) curve fitted the data reasonably well, considering that individual observations of length-at-age were used instead of the mean length-at-age. According to the obtained von Bertalanffy growth equation, *D. vulgaris* growth is intensive during first 4 years of its life with the growth rate slowing down considerably after the fish reaches 5 years of age.

The overall sex ratio was 1.22 : 1 in favour of males. A chi-square test revealed a non-significant departure from 1 : 1 sex ratio ($P < 0.05$).

Total mortality, corresponding to the slope of the descending limb of the length converted catch curve (Fig. 2), was $Z = 0.81$ per year for females and $Z = 0.85$ per year for males. Values of natural mortality were $M = 0.26$ per year for females and $M = 0.23$ per year for males. Calculation of fishing mortality gave $F = 0.55$ for females and $F = 0.62$ for males. With the values of M and F known, the exploitation ratios were then computed as $E = 0.68$ for females and $E = 0.73$ for males.

Discussion

Scales of the common two-banded seabream showed a regular growth pattern with clearly identifiable growth increments, which is in agreement with findings of Abecasis et al. (2008),

Table 2
Growth parameters of *Diplodus vulgaris*, Adriatic Sea, estimated by non-linear regression from scale readings of all data, mature fish combined, males and females. All lengths cm TL ± SE.

Parameters	All data	Mature fish combined	Females	Males
L_∞ (cm)	48.60 ± 1.101	54.06 ± 1.695	51.96 ± 2.153	56.25 ± 2.662
K (per year)	0.112 ± 0.005	0.089 ± 0.005	0.095 ± 0.007	0.084 ± 0.067
t_0 (year)	−2.366 ± 0.060	−2.875 ± 0.084	−2.837 ± 0.120	−2.920 ± 0.117

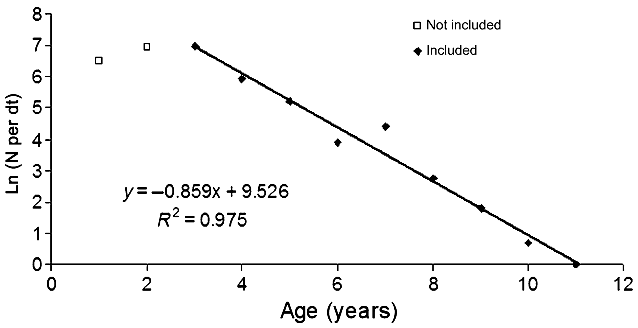

Fig. 2. Length-converted catch curve, *Diplodus vulgaris*, eastern Adriatic

who noted that both otoliths and scales of *D. vulgaris* proved to be easy to read with a high success rate in reading and interpretation of scales, indicating that this structure could be consistent enough for age determination. Although Abecasis et al. (2008) concluded that otoliths are more appropriate for age interpretation of common two-banded seabream, the fishermen did not allow us to collect them because of the high market value of this species. However, scales proved to be useful as an alternative non-destructive technique for ageing purposes.

The common two-banded seabream is a relatively long-lived species in the Adriatic Sea. The oldest specimen in this study was 11 years whereas Gonçalves et al. (2003) and Abecasis et al. (2008) reported oldest specimens of up to 14 years from the south and south-west coast of Portugal (Table 3). These values are the maximum observed age for *D. vulgaris*. Additionally, Man-Wai (1985) obtained a maximum age of 8 years by scale readings and 14 years by LFA analysis for individuals from the Gulf of Lyon. The von Bertalanffy growth parameters estimated by these investigators are given in Table 3. It is clear from Table 3 that these parameters vary significantly due to environmental and ecological factors present in different regions, but could also be a consequence of different methodologies used for fish ageing. In our case, the von Bertalanffy growth model explained more than 95% of the growth pattern observed in the common two-banded seabream. These results are in agreement with those of Gordoa and Moli (1997) for *D. vulgaris* off the Catalan coast and Pajuelo and Lorenzo (2003) for Canarian waters. However, in all published works on this species in which the von Bertalanffy growth model was applied, the estimations of t_0 tended to be negative and different from zero. These estimations suggest that the von Bertalanffy growth model does not accurately describe growth in the early stages (Gordoa and Moli, 1997). Several other authors report that early growth of Sparidae may not be adequately represented by the von Beratalanffy growth model, reporting that the first part of the curve corresponding to juveniles is rather linear (Monteiro, 1989; Macpherson, 1998; Vigliola et al., 1998) or could be described by the Gompertz equation (Matić-Skoko et al., 2004, 2007a). Comparing growth parameters obtained in this study with those presented by other authors, it is clear that the eastern Adriatic populations of this species approach the theoretical asymptotic length at the slowest rate (K value is the lowest among all calculated for this species). Such trade-offs between growth rate and asymptotic length are often found; these are influenced by several factors such as temperature, mortality and food availability. Although our growth coefficient value indicated relatively low rate of attainment of maximal size, it is worth mentioning that similar rates were found for other sparids in the eastern Adriatic. There is an obvious similarity in growth characteristics with *Diplodus annularis* (K = 0.126) (Matić-Skoko et al., 2007b), *Diplodus puntazzo* (K = 0.191) (Kraljević et al., 2007) and *Spondyliosoma cantharus* (K = 0.178) (Dulčić and Kraljević, 1996b) in the eastern Adriatic. The observed maximum length TL = 37.5 cm in this study is lower than the maximum observed values in the Adriatic; the previous values were TL = 45.4 (Cetinić et al., 2002) and TL = 50.0 cm (approx. W = 2500 g) (I. Jardas,

Table 3
Parameters of *Diplodus vulgaris* growth (Age, L_∞, K, t_0) from different study areas

Author	Location	Method	Age (year)	L_∞ (cm)	K	t_0
Girardin (1978)	Gulf of Lion	Scales	1–3	26.8 FL	0.26	−0.607
Man-Wai (1985)	Gulf of Lion	Scales	1–8	37.8 TL	0.18	−0.830
Mennes (1985)	Eastern Atlantic	LFA[a]	–	39.0 FL	0.40	–
Gordoa and Moli (1997)	NW Mediterranean	Otoliths	1–6	28.8 TL	0.39	−0.657
Gonçalves (2000)	SE Portugal	Otoliths	0–10	28.5 TL	0.30	−1.618
Pajuelo and Lorenzo (2003)	Canary Islands	Otoliths	1–9	39.7 TL	0.23	−0.908
Gonçalves et al. (2003)	SW Portugal	Otoliths	0–14	27.7 TL	0.40	−0.34
Abecasis et al. (2008)	South Portugal	Otoliths	0–14	27.4 TL	0.40	−0.77
		Scales	0–14	34.5 TL	0.18	−1.27
This study	Eastern Adriatic	Scales	1–11	48.6 TL	0.11	−2.366

[a]LFA, length frequency analysis; FL, fork length; TL, total length.

pers. comm.), probably representing the highest observed values for the entire area of distribution for which Bauchot (1987) reported maximal TL = 45.0 cm. In light of these findings, asymptotic lengths calculated in this study (L_∞ = 48.60 for all specimens, L_∞ = 56.25 cm for males, L_∞ = 51.96 cm for females) could not be considered as unrealistic. Although our estimated L_∞ values were higher than our largest observed fish, many authors found the opposite situation (Monteiro, 1989; Gordoa and Moli, 1997; Gonçalves et al., 2003; Pajuelo and Lorenzo, 2003) and concluded that this was due to deficiency of the von Bertalanffy model for describing growth of species from the family Sparidae, mainly due to their rapid growth in the first year of life and subsequent slowing of growth rate. In our study, when excluding immature specimens from the analysis the value of L_∞ is overestimated, while the value of K underestimated. In more general terms, it would be of great interest to determine to what extent the habitat conditions and modifies the growth pattern of the species in their different stages of development. It is clearly important to examine the growth of the juvenile stages of the species and incorporate this into studies of the adult population growth, since this could show in a very simple manner the inconsistency of an estimated growth pattern.

The mean size at first maturity of the common two-banded seabream in the study area (males 18.5 cm, females 19.1 cm) differs slightly from those reported in other areas of its distribution: Canary Islands – 19.7 cm (Lozano et al., 1990); Portuguese waters – males 17.27 cm, females 17.65 cm (Gonçalves et al., 2003), but is in agreement with those reported for the entire eastern Adriatic area: males 18.7 cm, females 19.5 (Cetinić et al., 2002). As reported by other authors (Man-Wai, 1985; Gordoa and Moli, 1997) there was a slight increase in the proportion of males with size, which could be related to the protandrous hermaphroditism associated with *D. vulgaris* (Gonçalves and Erzini, 2000) in those areas. However, hermaphroditism was not detected in the eastern Adriatic populations. The overall male : female ratio did not differ significantly from the theoretical 1 : 1, although it differed with season and length class. In general, differences in sex ratio in relation to length correspond with differences in growth and mortality rates, which have also been proposed for other fish species (e.g. Turner et al., 1983).

Pauly (1980) reviewed the natural mortality rates of 174 fish stocks, and modal mortality was between 0.2 and 0.3 (Vetter, 1988). The natural mortality of *D. vulgaris* in the area of study is 0.26 for females and 0.23 for males, indicating that values for the common two-banded seabream are within the reported range characterizing low natural mortality. Values of natural mortality (M = 0.753) obtained by Gonçalves et al. (2003) and (M = 0.66, for the NW African coast) Mennes (1985) were greater than obtained in this study, but one estimate (M = 0.21) by Man-Wai (1985) was similar to ours. A review based on ten species of Sparidae from the Mediterranean and NW Atlantic showed that estimated natural mortality rates ranged from 0.19 to 0.66, with a mean of 0.36 (Erzini et al., 2001). It is obvious that M estimated in this study is well within the range of values for similar sized seabreams. The estimated fishing mortality rates and exploitation rates obtained in this study were in all cases fairly high, indicating a high fishing pressure on the stock. However, the exploitation rate estimate should be considered with caution, since estimated total mortality was based on a relatively short sampling period (1 year) and may be biased due to annual differences in year-class strength. We must also take into account that obtained results are within the domain of first estimate. In future, appropriate investigations and longer-term sampling should be required to verify this initial guessing. As catches from commercial 'tramata' fishing do not include a significant part of the undersized *D. vulgaris*, analysis of size selectivity and mortality rates should be taken with caution, because results may be biased without considering catches of this species for all types of gear in present use. Particularly the low values of fishing mortality may give an incorrect interpretation of 'healthy stock'. It is more realistic that due its relatively high commercial value, *D. vulgaris* appears to be under some fishing pressure, which is not yet sufficiently quantified.

Acknowledgements

Authors would like to thank the Ministry of Science, Education and Sport of Republic of Croatia for the financial support of Project 001-0013077-0844.

References

Abecasis, D.; Bentes, L.; Coelho, R.; Correia, C.; Lino, P. G.; Monteiro, P.; Gonçalves, J. M. S.; Ribeiro, J.; Erzini, K., 2008: Ageing seabreams: a comparative study between scales and otoliths. Fish. Res. **89,** 37–48.

Bauchot, M. L., 1987: Poissons osseux. In: Fiches FAO d'identification pour les besoins de la pêche. (rev. 1). Méditerranée et mer Noire. Zone de pêche 37, Vol. II. W. Fischer, M. L. Bauchot and M. Schneider (Eds). Commission des Communautés Européennes and FAO, Rome, pp. 891–1421.

Bauchot, M. L.; Hureau, J. C., 1986: Sparidae. In: Fishes of the North-eastern Atlantic and the mediterranean. II. In: P. J. P. Whitehead, M. L. Bauchot, J. C. Hureau, J. Nielsen and E. Tortonese. (Eds). UNESCO, Paris, pp. 883–907.

Beamish, R. J.; Fournier, D. A., 1981: A method for comparing the precision of a set of age determination. Can. J. Fish. Aquat. Sci. **38,** 982–983.

Cetinić, P.; Soldo, A.; Dulčić, J.; Pallaoro, A., 2002: Specific method of fishing for Sparidae species in the eastern Adriatic. Fish. Res. **55,** 131–139.

Chang, W. B., 1982: A statistical method for evaluating the reproducibility of age determinations. Can. J. Fish. Aquat. Sci. **39,** 1208–1210.

Dulčić, J.; Kraljević, M., 1996a: Weight-length for 40 fish species in the Eastern Adriatic (Croatian waters). Fish. Res. **28,** 243–251.

Dulčić, J.; Kraljević, M., 1996b: Growth of the black sea bream, *Spondyliosoma cantharus* (L.) in the eastern middle Adriatic. Arch. Fish. Mar. Res. **44,** 279–293.

Dulčić, J.; Kraljević, M.; Grbec, B.; Pallaoro, A., 1997: Composition and seasonal fluctuations of inshore juvenile fish populations in the Kornati archipelago, eastern middle Adriatic. Mar. Biol. **129,** 267–277.

Erzini, K.; Gonçalves, J. M. S.; Bentes, L.; Lino, P. G.; Ribeiro, J., 1998: Species and size selectivity in a 'red' sea bream longline métier in the Algarve (southern Portugal). Aquat. Living Resour. **11,** 1–11.

Erzini, K.; Bentes, L.; Coelho, R.; Correia, C.; Lino, P. G.; Monteiro, P.; Ribeiro, J.; Gonçalves, J. M. S., 2001: Fisheries biology and assessment of demersal species (Sparidae) from the south of Portugal. UE-DG XIV-98 ⁄ 082. Final report, pp. 1–263.

Gayanilo, F. C., Jr; Sparre, P.; Pauly, D., 1994: The FAO-ICLARM stock assessment tools (FiSAT) user's guide. Fao Computerized Information Series (Fisheries). FAO Rome **6,** 186.

Girardin, M., 1978: Les sparides (Pisces Teleostei) du golfe du lion. Ecologie et biogeographie. DEA. Université des Sciences et Techniques du Languedoc, Montpellier, pp. 147.

Gonçalves, J. M. S., 2000: Biologia pesqueira e dinamica populacional de *Diplodus vulgaris* (Geoffr.) e *spondyliosoma cantharus* (L.) (Pisces, Sparidae) na costa sudoeste de Portugal. Tese de doutoramento, Universiddae do Algarve, UCTRA, Faro, pp. 369.

Gonçalves, J. M. S.; Erzini, K., 2000: The reproductive biology of two-banded sea bream (*Diplodus vulgaris*) from the SW coast of Portugal. J. Appl. Ichthyol. **16,** 110–116.

Gonçalves, J. M. S.; Bentes, L.; Coelho, R.; Correia, C.; Lino, P. G.; Monteiro, C. C.; Ribeiro, J.; Erzini, K., 2003: Age and growth, maturity, mortality and yield-per-recruit for two banded bream (*Diplodus vulgaris* Geoffr.) from the south coast of Portugal. Fish. Res. **62,** 349–359.

Gordoa, A.; Moli, B., 1997: Age and growth of the sparids *Diplodus vulgaris*, *D. sargus* and *D. annularis* in adult populations and the differences in their juvenile growth patterns in the north-western Mediterranean Sea. Fish. Res. **33,** 123–129.

Grubišić, F., 1982: Ribe, rakovi i školjke jadrana. ITRO Naprijed, Zagreb-GRO Liburnija, Rijeka, pp. 240.

Gulland, J. A., 1971: The fish resources of the ocean. Fishing News (for the Food and Agriculture Organization), West Byfleet, UK, pp. 255.

Jardas, I., 1996: Adriatic ichthyofauna. Školska knjiga, Zagreb, pp. 533.

Kraljević, M.; Matić-Skoko, S.; Dulčić, J.; Pallaoro, A.; Jardas, I.; Glamuzina, B., 2007: Age and growth of sharpsnout seabream *Diplodus puntazzo* (Cetti, 1777) in the eastern Adriatic Sea. Cah. Biol. Mar. **48,** 145–154.

Lozano, I.; Caldentey, M. A.; Gonzalez, J. A.; Carrollo, J.; Santana, J. I., 1990: Talla de primera madurez sexual de seis esparidos de interes pesquero en Canaries. Inf. Tec. Inst. Esp. Oceanogr. **84,** 1–30.

Macpherson, E., 1998: Ontogenetic shifts in habitat use and aggregation in juvenile sparid fishes. J. Exp. Mar. Biol. Ecol. **220,** 127–150.

Man-Wai, R., 1985: Les sars du Golfe du Lion. *Diplodus sargus*, *D. vulgaris*, *D. annularis* (Pisces, Sparidae). Ecobiologie-pêche. Thèse Docteur. Université des Sciences et Techniques du Languedoc, Montpellier, pp. 361.

Matić-Skoko, S.; Kraljević, M.; Dulčić, J.; Pallaoro, A., 2004: Growth of juvenile salema, *Sarpa salpa* (Teleostei: Sparidae), in the Kornati Archipelago, eastern Adriatic Sea. Sci. Mar. **68,** 411–417.

Matić-Skoko, S.; Kraljević, M.; Dulčić, J.; Pallaoro, A.; Lučić, D.; Glamuzina, B., 2007a: Growth of juvenile sharpsnout seabream, *Diplodus puntazzo* (Teleostei: Sparidae) in the Kornati archipelago, Eastern Adriatic Sea. Vie Milieu. **57,** 13–19.

Matić-Skoko, S.; Kraljević, M.; Dulčić, J.; Jardas, I., 2007b: Age, growth, maturity, and yield-per-recruit for annular sea bream (*Diplodus annularis* L.) from the eastern middle Adriatic Sea. J. Appl. Ichthyol. **23,** 152–157.

Mennes, F., 1985: Multispecies assessment of fish stocks off the Western Sahara region with emphasis on the family Sparidae. NAGA **3,** 5–10.

Monteiro, P., 1989: La faune ichthyologique de la lagune Ria Formosa (Sud Portugal). Répartition et organisation spatio-temporelle des communautés à l'aménagement des ressources. Thèse Doctorat. Université des Sciences et Techniques du Languedoc, Montpellier. pp. 219.

Pajuelo, J. G.; Lorenzo, J. M., 2003: The growth of th ecommon two-banded seabream, *Diplodus vulgaris* (Teleostei, Sparidae), in Canarian waters, estimated by reading otoliths and by back-calculation. J. Appl. Ichthyol. **19,** 79–83.

Pajuelo, J. G.; Lorenzo, J. M.; Bilbao, A.; Ayza, O.; Ramos, A., 2006: Reproductive characteristics of the benthic coastal fish *Diplodus vulgaris* (Teleostei: Sparidae) in the Canarian archipelago, north-west Africa. J. Appl. Ichthyol. **22,** 414–418.

Pallaoro, A.; Krstulović, S.; Kraljević, M., 1994: Ishrana mlađi fratra (*Diplodus vulgaris*) (Pisces, Sparidae) u srednjem Jadranu. Zbornik sažetaka priopćenja V kongresa biologa Hrvatske, pp. 226.

Pauly, D., 1980: On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 174 fish stocks. J. Cons. Int. Explor. Mer. **39,** 175–193.

Pauly, D., 1984: Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Stud. Rev. **8,** 325.

Rosecchi, E., 1987: L'alimentation de *Diplodus annularis*, *Diploldus sargus*, *Diplodus vulgaris* et *Sparus aurata* (Pisces, Sparidae) dans le Golfe du Lion et les lagunes littorales. Rev. Inst. Pêches Marit. **49,** 125–141.

Turner, S. C.; Grimes, C. B.; Able, K. W., 1983: Growth, mortality and age ⁄ size structure of the fisheries for tilefish, *Lopholatilus chaemaelonticeps*, in the middle Atlantic-southern New England region. US Fish. Bull. **81,** 751–763.

Vetter, E. F., 1988: Estimation of natural mortality in fish stocks. US Fish. Bull. **86,** 25–43.

Vigliola, L.; Harmelin-Vibžvien, M. L.; Biagi, F.; Galzin, R.; Garcia-Rubies, A.; Harmelin, J. G.; Jouvenel, J. Y.; Le Direach-Boursier, L.; Macpherson, E.; Tunesi, L., 1998: Spatial and temporal patterns of settlement among sparid fishes of the genus *Diplodus* in the northwestern Mediterranean. Mar. Ecol. Prog. Ser. **168,** 45–56.

Williams, T.; Bedford, B. C., 1974: The use of otoliths for age determination. In: The ageing of fish, proc internat symposium. T. B. Bagenal (Ed.). Unwin Brothers, Surrey, pp. 114–123.

Author's address: Jakov Dulčić, Institute of Oceanography and Fisheries, PO Box 500, HR-21000 Split, Croatia. E-mail: dulcic@izor.hr