Arquipelago - Life and Marine Sciences ISSN: 0873-4704

Age and growth of the pink dentex *Dentex gibbosus* (Rafinesque, 1810) caught off the Madeira Archipelago

ADRIANA ALVES & JOANA VASCONCELOS

Alves, A. & J. Vasconcelos 2012. Age and growth of the pink dentex *Dentex gibbosus* (Rafinesque, 1810) caught off the Madeira Archipelago. *Arquipelago*. Life and Marine Sciences 30: 1-9.

A total of 146 otoliths were extracted for age readings from 68 females (23.2-90.1 cm TL), 76 males (22.0-81.3 cm TL) and 2 undetermined (30.3-38.0 cm TL), between April 2004 and December 2007. The maximum age obtained from whole otoliths was 11 years. Differences in the growth rhythms were observed between the sexes (females: $L\infty$=134.4, K=0.092 and t0=−0.406; males: $L\infty$=135.9, K=0.078 and t0=−0.894; and all fish were: $L\infty$=149.8, K=0.078 and t0=−0.784). Pink dentex attain 50% of their maximum theoretical length during their fourth year of life. The weight-length relationship (W = q Lfb) were determined separately for each sex and for all fish: for females q=0.01094 and b=3.033, for males q=0.10002 and b=3.047 and for all, q=0.01027 and b=3.046. According to the F-test, there were no significant differences between the weight-length relations obtained for females and males (F-test, F=2.2526, p=0.06646).

Key words: *Dentex gibbosus*, age and growth, weight-length relationships, Madeira Island

Adriana Alves (e-mail: adrianaalves.sra@gov-madeira.pt) & Joana P.R. Vasconcelos, Direcção de Serviços de Investigação das Pescas/Regional Directorate of Fisheries (DRP), Estrada da Pontinha, PT-9004-562, Funchal, Madeira, Portugal.

INTRODUCTION

The pink dentex, *Dentex gibbosus* (Rafinesque, 1810) (Fig. 1) is a demersal marine fish associated with a variety of temperate to subtropical habitats. This species is distributed throughout the Mediterranean and east Atlantic coasts, from Portugal to Angola (Fernandez-Palacios et al. 1994; Pajuelo & Lorenzo 1995). It is captured from 20 and 400 m depth. Juvenile individuals occur mainly in coastal waters, while adult are found in deeper waters, up to the limit of the continental shelf.

As a carnivorous species, its natural diet is composed mainly of teleosts, crustaceans and cephalopods (Bauchot et al. 1981; Bauchot & Hureau 1986). Adult individuals present a marked protuberance on their forehead. The two second rays of the dorsal fin are long and filamentous in juveniles. This characteristic is lost in adults (Fernández-Palacios et al. 1994).

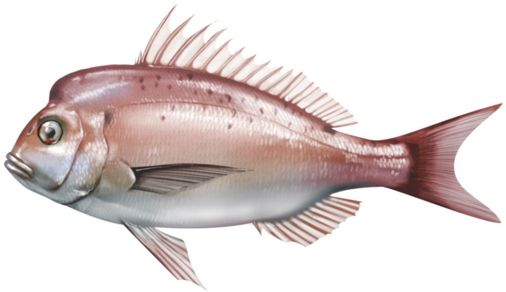

Fig. 1 - Illustration of an adult *Dentex gibbosus* (Rafinesque 1810) caught in Madeira Island (©DRP).

This species is usually consumed fresh and is captured by local artisanal boats fishing with bottom longlines and handlines, which operate around Madeira and Porto Santo islands and

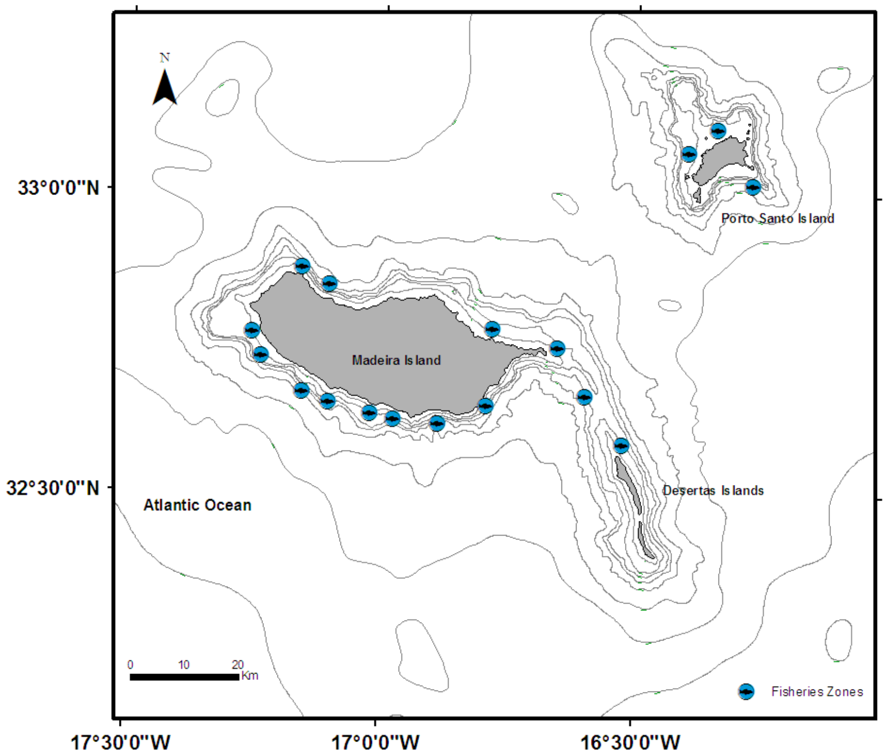

Fig. 2. Location of the main fisheries zones (black dots) for *Dentex gibbosus* in Madeira Archipelago according to available positional data (DRP).

occasionally off Desertas Island (Fig. 2). In 2011, 2.9 tons (17 thousand euros) were landed, representing 4.6% and 6.1% of the demersal landings in weight and value, respectively.

The type of hermaphroditism in this species is uncertain as different studies report conflicting evidence regarding this feature. Grubisic et al. (2007) concluded that this species is a rudimentary hermaphrodite in the Adriatic Sea. According to Pajuelo & Lorenzo (1995) this species displays protogynous hermaphroditism in the Canary Islands, whereas Bonnet (1969) reported that pink dentex off North-West Africa appeared to display protandrous hermaphroditism. In the Madeira Archipelago, it should be noted that no type of hermaphroditism was observed in the individuals sampled (Alves et al. 2011).

Understanding the life history of a species is an important and essential step towards the assessment of its potential as an exploitable resource. Two of the most important aspects of fish life-history are growth and reproduction because these are the biological processes that replenish the biomass taken by mortality. Accuracy and precision in biological evaluation are of crucial importance in stock assessment.

Age estimates from band counts on aging structures (such as otoliths) and validation of the periodicity of their deposition are basic requirements to obtain growth rates, ages at maturity and recruitment, longevity and natural mortality rates (Peres & Haimovici 2004).

Despite its abundance and commercial value, there is little information about the biology of this species in this area. Abdelkader & Ktari (1983) described the morphological characteristics of the species off Tunisia and Fernández-Palacios et al. (1994) studied embryonic and larval development under controlled conditions in Gran Canaria (Canary Islands). Pajuelo & Lorenzo (1995) studied biological parameters reflecting the currents state of the population off the Canary Islands. Grubisic et al. (2007) studied the reproductive biology and fecundity of this species from the Adriatic Sea.

The aim of the present study was to provide information on age, growth and weight-length relationship of the pink dentex population in the Madeira archipelago, which are important input parameters to stock assessment techniques and will provide an insight into the life history of this species.

MATERIAL AND METHODS

SAMPLING

A total of 146 specimens of *Dentex gibbosus* were collected between 2004-2007 from scientific cruises and commercial landings. Fish were caught with horizontal bottom longlines and hand lines for demersal species. The fishing depth varied from 20 to 200 m.

For each fish, total length (TL) was measured to the nearest millimetre and total wet weight (TW) were recorded to the nearest 0.01g. Sex was determined through macroscopic examination of gonads and validated microscopically using a histological technique (Alves et al. 2011). *Sagitta* otoliths were removed, cleaned, dried and stored in labelled plastic vials.

AGE DETERMINATION

Ages were assigned by counting growth marks on 146 whole otoliths (68 females, 76 males and 2 undetermined), collected between April 2004 and December 2007, and assumed to be annual. Otoliths were examined using reflected light, immersed in 70º alcohol and against a dark background, under a compound microscope Leica MZ95 (6.3x magnification). Two separate readings were made, without knowledge of the size and sex of the specimens or previous counts, and only identical values were considered valid. When there was a discrepancy between the two readings, a third reading was carried out. It was assumed that this species forms one true translucent zone and one true opaque zone every year. The formation of the complex of both zones takes place in one year and is defined as an annulus (Monooch & Huntsman 1977; Morales-Nin, 1987; Dawson 1991)

GROWTH IN LENGTH

The von Bertalanffy growth model (1) was fitted to observed length-at-age data (Gulland 1983; Francis 1995) by means of the Gauss-Newton algorithm for non-linear parameter estimation using Statistica 6.0 (Statsoft 2001), as follows (Beverton & Holt 1993):

$$L_t = L_\infty [1 - e^{-k\,(t-t0)}] \qquad (1)$$

Where L_t is the fish total length at age t (cm); L_∞ the asymptotic mean length (cm); k the VB growth coefficient (yr^{-1}); and t_0 the hypothetical age when fish length is zero (yr). The growth coefficient (k) describes the curvature of a growth curve while t_0 acts as an adjustment factor moving the curve to the left or right (Bagenal & Tesch 1978; Jones 2002).

The mean lengths at age and the von Bertalanffy growth parameters estimated in this study and reported by other authors were compared using the student's t-test (Zar 1996) and the index of growth performance φ' (Φ'=2logL_∞ + log$k$, Munro & Pauly 1983), respectively. Bertalanffy growth curves were compared between sexes by using an F-test (Zar 1996).

WEIGHT-LENGTH RELATIONSHIP

For the weight-length relationship, a total of 146 individuals were used. The weight-length relationships (2) were obtained by least squares linear regression after log transformation of both variables. An exponential curve was fitted to the data (Jones 2002):

$$TW = q.\ TL^b \qquad (2)$$

Where TW is the total weight (g), TL is the fish total length (cm), q is a constant (condition factor) and b is the growth coefficient (i.e., fish relative growth rate).

A t-test (Zar 1996) was used to test the null hypothesis H_0: b = 3 (isometric growth) at 5%

significance level. The *F*-test was also applied to compare male and female length-weight relationships. Growth in weight was estimated by using Richard's growth equation (Cadima 2003; Haddon 2001) that combines the von Bertalanffy growth in length equation (1) with the length weight relationship in equation (2), when allometry (b≠3) exists:

$$W_t = W_\infty [1 - e^{-k\,(t-t0)}]^{\,b} \qquad (3)$$

Where W_∞ is the mean asymptotic weight (g), Wt is the mean weight (g) at age t (yr), k is the growth coefficient (yr^{-1}), t is the individual age (yr), t_0 is the theoretical age at which weight is zero (yr) and b is the coefficient of allometry.

RESULTS

Of all individuals examined, 68 were females and 76 males. The sex of the remaining 2 individuals could not be identified macroscopically. The size range of the all individuals was between 22.0 and 90.1 cm TL (23.2- 90.1 cm TL for females; 22.0 – 81.3 cm TL for males and 30.3-38.0 cm TL for undetermined).

AGE DETERMINATION

Sagitta otoliths of *D. gibbosus* show the ring pattern common to teleost fishes (Williams & Bedford 1974).

These increments are formed during alternative periods of fast and slow growth (Williams & Bedford 1974; Morales-Nin 1987; Abaunza et al. 2003). By assuming that otolith increments are formed annually throughout the entire lifespan of the individual, the number of annuli counted was converted into ages.

The age of the fish studied ranged from 1 to 11 years. The age group 2 was the best represented (n=37). There were significant differences between sexes in mean lengths at age 1 and 8 (t-Student, p<0.05) (Table 1).

GROWTH IN LENGTH

The von Bertalanffy model was fitted to the mean length at age estimated for females, males and all individuals (Table 2 and Fig. 3). No significant differences in growth parameters were found between sexes (F=-0.000116; p=0.999).

Table 1. Mean lengths at age (Lt) and standard deviation (SD) estimated for females (F), males (M) and total (T) of *D. gibbosus,* in the period 2004-2007.

Age group	Females			Males			Total		
Year	**N**	**Lt**	**SD**	**N**	**Lt**	**SD**	**N**	**Lt**	**SD**
1	3	29.0	3.6	9	23.4	1.6	12	24.8	3.2
2	19	30.8	3.7	17	30.1	2.8	37	30.5	3.2
3	11	36.6	4.6	13	36.5	5.5	25	36.6	4.9
4	7	49.1	5.3	10	46.8	4.7	17	47.8	4.9
5	4	53.0	10.0	12	56.5	7.3	16	55.6	7.9
6	3	64.7	5.5	4	63.0	9.9	7	63.7	7.7
7	4	70.8	8.7	3	63.0	7.0	7	67.4	8.4
8	8	78.8	4.3	7	70.6	3.5	15	74.9	5.7
9	4	80.0	6.9	2	70.5	2.1	6	76.8	7.3
10	2	86.0	2.8	1	81.0		3	84.3	3.5
11	3	80.7	5.1	1	81.0		4	80.8	4.2

Table 2. Von Bertalanffy growth parameters estimated for females, males and total of *D. gibbosus*, in the period 2004-2007.

Sex	N	TL range (cm)	L_∞ (cm)	k (year-1)	t_0 (year)	r^2
Females	68	23.2-90.1	134.45	0.0915	-0.4060	0.961
Males	76	22.0-81.3	132.43	0.0818	-0.840	0.946
Total	146	22.0-90.1	146.28	0.0750	-0.7336	0.954

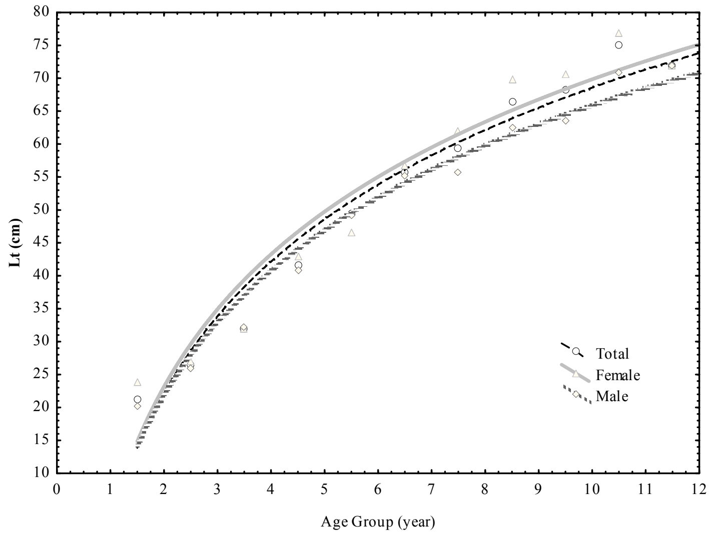

Fig. 3. Von Bertalanffy growth curves fitted for females, males and all individuals of *D. gibbosus,* in the period 2004-2007.

WEIGHT-LENGTH RELATION

The theoretical mean maximum weight was similar for males and females, but considerably heavier when the growth curve was fitted to all fish combined (Table 3).

Table 3. Asymptotic weight (W∞) and length weight relationship parameters (relative condition factor, *q* and allometric coefficient (*b*), estimated by sex and for sexes combined (all fishes), for *Dentex gibbosus* caugth off Madeira Island in 2004-2007. r^2= coefficient of determination.

Sex	N	W∞ (g)	q	b	r^2
Females	68	31330	0.01094	3.03	0.988
Males	76	31794	0.01002	3.05	0.996
Total	146	43337	0.01027	3.05	0.992

No significant differences were found in length weight relationship parameters between sexes (F-test; F=2.253; p=0.07). The length-weight relationship estimated for all fishes combined (Fig. 4) was estimated as follows:

$$TW= 0.0103\ TL^{3.0456}$$

A positive allometric growth in weight (*b*>3) was found ($t_{0.05;144} = 1.9766$; t = 1.9463).

Since no significant differences were found between sexes, growth in weight parameters were also estimated for sexes combined. The Richard's growth in weight equation, for sexes combined, was estimated as follows:

$$W_t= 43337\ [1 - e^{-0.0720(t+0.7836)}]^{3.0456}$$

Where *Wt* is the mean weight (g) at age *t* (yr).

DISCUSSION

The results presented in this study are a contribution to more accurate estimations of the mean length at age and growth parameters of *D. gibbosus* in the Madeira archipelago, based on otolith interpretation. 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. In the present study, the use of whole-view examination of otoliths permitted the direct comparison with published results for the region.

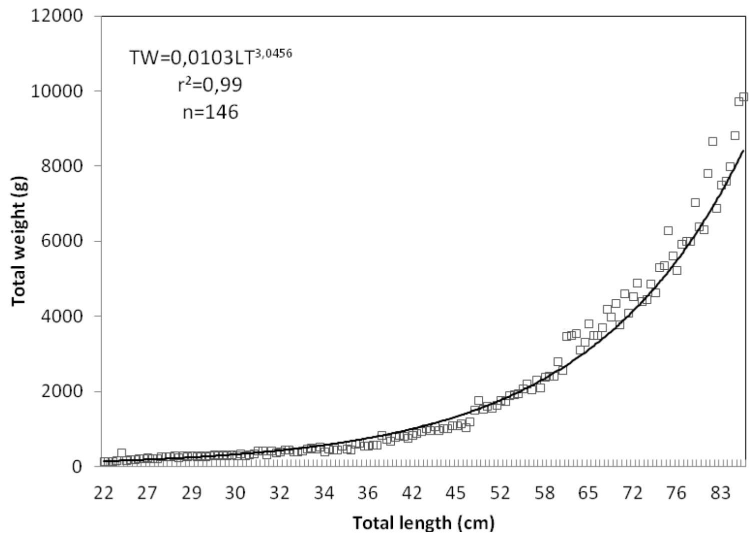

Fig. 4. Weight-length relationship estimated for *D. gibbosus* off Madeira archipelago sampled in the period 2004-2007.

Table 4. Von Bertalanffy length growth parameters (L_∞, k and t_0) estimated for *Dentex gibbosus* (sexes combined), from direct reading of otoliths in the present (1) study and by other authors (2 Pajuelo & Lorenzo 1995; 3 Mennes 1985; 4 Nguyen & Wojciechowski 1972; 5 Grubisic et al. 2007); L = length, N = sample size, r^2 = coefficient of determination; Φ' is the Pauly's growth performance index used for growth parameters comparisons.

Source	**Geograph. Area**	**Method**	**L**	**N**	**Size range**	**Age range**	**L_∞ (cm)**	**k (yr^{-1})**	**t_0 (yr)**	**r^2**	***Φ'***
1	Madeira	Otoliths	TL	146	22.0 to 90.1	1-11	146.28	0.0750	-0.733	0.954	3.21
2	Canaries	Otoliths	TL	639	14.2 to 95.2	0-16	101.2	0.149	-0.111	0.987	3.15
3	Marroco	Length-frequenc.	FL				86.0	0.19			3.15
4	Mauritânia	Otoliths	TL				107.0	0.124	-0.6		3.15
5	Croatia	Otoliths	TL				107.2	0.12	-0.9		3.14

Pink dentex growth has been studied by various authors in the Atlantic Ocean (Table 4). Some of these results are illustrated and compared in Fig. 5. The growth study using otoliths direct reading has been used in Atlantic Ocean by Pajuelo & Lorenzo (1995), Nguyen & Wojciechowski (1972), Mennes (1985) and Grubisic et al. (2007).

The age range observed in this study (1 to 11 years) was smaller than the obtained by Pajuelo & Lorenzo (1995) for pink dentex present in the Canary Islands (0 to 16 years).

The mean length-at-age 1 to 11 estimated in this study and in Pajuelo & Lorenzo (1995) were compared. There were significance differences (t-test: $p<0.05$), except the 2 and 10 age groups.

The fitted von Bertalanffy growth curves obtained for sexes combined of *D. gibbosus* in the present and other studies are shown in Fig. 5.

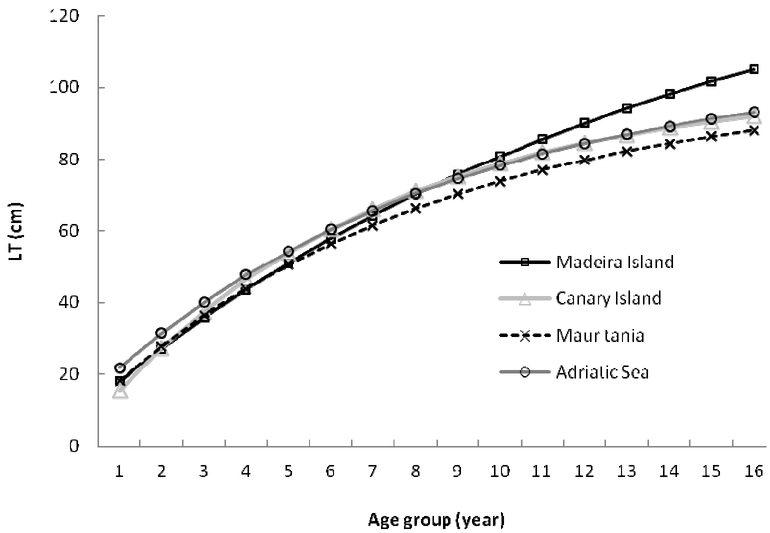

Fig. 5. von Bertalanffy growth curves obtained for sexes combined of *Dentex gibbosus* in the present and other studies, Canary Islands (Pajuelo & Lorenzo 1995), Mauritania (Nguyen & Wojciechowski 1972) and Adriatic Sea (Grubisic et al. 2007).

Pink dentex attained 50% of their maximum theoretical length during their fourth year of life. After completing the fourth year, the annual growth rate drops, perhaps due to sexual maturity (50% pink dentex are mature by their fourth year).

Considering the results from the published literature, von Bertalanffy growth parameters estimated by different methods and even by the same method, showed discrepancies for both L_∞ and k values. The theoretical maximum length estimated in this study was too high regarding to the size of the largest fish sampled and the growth coefficient was low. The lack of small fish in the present study leads to an overestimation of the L_∞ and consequently an underestimation of k.

The asymptotic length (L_∞) values obtained for the Madeira population were higher than those obtained by Mennes (1984) for *D. gibbosus* off Marocco (length frequency method; L_∞ =86 cm, k=0.19 year $^{-1}$) by Pajuelo & Lorenzo (1995) in Canary Islands (L_∞ =101.2 cm, k=0.149 year $^{-1}$) and by Grubisic et al. (2007) in the Adriatic Sea (L_∞ =107.24 cm, k=0.12 year $^{-1}$) (Table 4).

This parameter can be influenced by the number of observed age groups and by the sampling of older age, since the lack of large individuals may have contributed partly to unrealistic high L_∞ values obtained in this present study. This discrepancy may be due to the difference in the size of the largest fish sampled in both areas rather than to the methodology employed. The largest fish sampled by Mennes (1984) was only 60 cm total length and in this present study was 90.1 cm TL.

The differences for these discrepancies may be related to several factors. There is a settled minimum size limits for the capture of red porgy (20 cm in total length) however, as these two species are caught together, this size limit is also valid for the pink dentex. This can be seen in the lengths frequencies distribution observed in this study and in the Canary Islands (Pajuelo & Lorenzo 1995). Gear selectivity may be a factor that could explain the differences between studies, since the type of gear used in Madeira Islands (hand lines and bottom longline), Canary Islands and Morocco (traps) were different.

Differences in fishing pressure could also explain some of the differences observed. In Madeira Islands there is no specific fishery for pink dentex, however in Canary Islands (Pajuelo et al. 1995) this species are heavily exploited according to the value of E (exploitation rate) calculated in their study.

Differences in growth patterns can be the result of differences in genetic structure and / or differences in temperature, density of food and diseases (Pauly 1994; Wootton 1998). The comparison of growth performance index of pink dentex from the Atlantic Ocean showed that Φ values in Madeira Islands were lower than those in the others Atlantic Ocean areas (Table 4), maybe due to the small sample size.

The b parameter value of the weight-length relationship obtained in this study was different to the estimate by Pajuelo & Lorenzo (1995). No significant differences were found in length-weight relationship parameters between sexes. Furthermore, the length-weight relationship revealed that males are heavier at a given length than females. Data also indicated that weight increases allometrically with length for both sexes in this study and in Pajuelo & Lorenzo (1995) (Table 3).

A larger sample size would improve our results, namely regarding the mean lengths at age estimation. Moreover, the zero age group is not represented in the present study, since individuals smaller than 20 cm were not found.

An interesting study in this line of work would be the growth of young fish in captivity, since their capture in the fishery is limited, caused by the selectivity of the gear. Setting up a continuous biological sampling programme is strongly recommended in order to obtain more data and the use of back-calculated size-at-age data because they more accurately estimate true growth (Ricker 1969).

ACKNOWLEDGEMENTS

We would like to thank the staff at the DSIP Laboratory (Direção de Serviços de Investigação das Pescas) for their assistance in sampling and management of fish and Antonieta Amorim for supplying the map used in this paper. Thanks are also due to MEIO companies, for providing the illustration of *Dentex gibbosus*. We would also like to express our thanks to two anonymous referees for reviewing the manuscript.

REFERENCES

Abdelkader, B. & M.H Ktari 1983. Étude des dentes des côtes tunisiennes: morphologie et production. *Bulletin de l'Institut National Scientifique et Technique d`Océanographie et de Pêche, Salammbô* 10 : 55-67.

Abaunza, P., L. Gordo, C. Karlou-Riga, A. Murta, A.T.G.W. Eltink, M.T.G. Santamaria, C. Zimmermann, C. Hammer, P. Lucio, S.A. Iversen, J. Molloy & E. Gallo 2003. *Growth and reproduction of horse mackerel, Trachurus trachurus (Carangidae). Reviews in Fish Biology and Fisheries* 13: 27-61.

Alves, A., G. Faria, R. Reis, A.R. Pinto & S. Vieira 2011. Aspects of reproduction in pink dentex *Dentex gibbosus* (Rafinesque, 1810) from the Archipelago of Madeira in the northeast Atlantic. *Arquipelago*. Life and Marine Sciences 28: 71-82.

Bagenal, T.B. & F.W. Tesh 1978. Age and growth. Pp 101-136 in : Bagenal, T. (Ed.). *Methods for Assessment of Fish Production in Freshwaters.* Blackwell Scient. Publ. Ltd. Oxford, England.

Bauchot, M.L. & J.C. Hureau 1986. Sparidae. Pp. 883-907 in: *Fishes of the Northeastern Atlantic and the Mediterranean*. P.J.P, Whitehead, M.L. Bauchot, J.C., Hureau, J.C. Nielsen & E. Tortonese (Eds) Paris, UNESCO.

Bauchot, M.L., J.C. Hureau & J.C. Miquel 1981. Sparidae. Pp. 41-81 in: W. Fischer et al. (Eds), *Fiches FAO d'identification des espèces pour les besoins de la pêche. Atlantique centre-est; zones de pêche 37 et 42 (en partie)*. FAO. Canada, vol. IV.

Beverton, R.J.H. & S. J. Holt 1993. On the Dynamics of Exploited Fish Populations. Fish and Fisheries Series 11, London: Chapman & Hall. 537 pp.

Bonnet, M. 1969. Les sparides des côtes Nord-Ouest Africaines. *Revue des Travaux de l'Institut des Pêches Maritimes* 33 (1): 97-116.

Cadima, E.L. 2003. Fish Stock Assessment Manual. FAO Fish. Tech. Pap. 393, Roma. Available online at http://www.fao.org/docrep/006/X8498E/X8498E00.HTM

Dawson, W. 1991. Otolith measurement as a method of identifying factors affecting first-year growth and stock separation of mackerel (*Scomber scombrus*, L.). *Journal du Conseil International pour Exploration de la Mer* 47: 303-317.

Fernández-Palacios H., D. Montero, J. Socorro, M.S. Izquierdo & J.M. Vergara 1994. First studies on spawning, embryonic and larval development of *D. gibbosus* (Rafinesque, 1810) (Osteichthyes, Sparidae) under controlled conditions. *Aquaculture* 122: 63-73.

Francis, R.I.C.C. 1995. The analysis of otolith data – a mathematician's perspective (what, precisely, is your model?). Pp. 81-95 in *Recent Developments in Fish Otolith Research.* Ed. by Secor, D.H., Dean, J.M., Campana, S.E.. The Belle W. Baruch Library in Marine Science 19. University of South Carolina Press, Columbia, SC.

Grubisic, L., G.J. Mrcelic, N. Skakelja, I. Katavic, V. Ticina & M. Sliskovic 2007. Reproductive biology of pink dentex Dentex gibbosus (Rafinesque) from the Adriatic Sea, Croatia. *Aquaculture Research* 38 (9): 991-1011.

Gulland, J. 1983. *Fish stock assessment: A manual of basic methods*. John Wiley & Sons. vol.1: 87-96.

Haddon, M. 2001. *Modeling and quantitative methods in fisheries*. Chapman &360 Hall/CRC, 406 pp.

Jones, C.M. 2002. Age and Growth. Pp. 33-63 in: *Fishery Science, the unique contributions of early life stages*. Ed. by Fruiman, L.A., Werner, R.G. Blackwell Science, Oxford.

Mennes, F. 1984. Assessments of the stocks of Sparidae and *Trachurus trachurus* off Marocco. *Tech. Pap. Commum. east. cent. Atl. Fish.* 84/62: 170 pp.

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

Monooch, C.S. III & G.R. Huntsman 1977. Age, growth, and mortality of the red porgy, *Pagrus pagrus*. *Transactions of the American Fisheries society* 106: 26-23.

Munro, J. L. & D. Pauly 1983. A simple method for comparing growth of fishes and invertebrates. *ICLARM Fishbyte* 1(1): 5-6.

Morales-Nin, B. 1987. Métodos de determinación da la edad en los osteictios en base a estruturas de crescimiento. *Informes Técnicos de Investigacion Pesquera* 143, 30 pp.

Nguyen, X. L. & J. Wojciechowski 1972 Comparative biology of fish from genus *Dentex* (Sparidae) of north-west African coast. *Acta Ichthyologica et Piscatoria* 2(2): 77-79.

Pajuelo J.G. & J.M. Lorenzo 1995. Biological parameters reflecting the current state of the expliotated pink dentex *Dentex gibbosus* (Pisces: Sparidae) population off the Canary Islands. S*outh African Journal of Marine Sciences* 16: 311-319.

Pauly, D. 1994. On the Sex of the Fish and the Gender of Scientists: *A collection of essays in fisheries science*. Chapman & Hall, London, UK. 250p.

Peres, M.B. & M. Haimovici 2004. Age and growth of southwestern Atlantic wreckfish *Polyprion americanus*. *Fisheries Research* 66: 157-169.

Ricker, W.E. 1696. Effects of size-selective mortality and sampling bias on estimates of growth, production and yield. *Journal of the Fisheries Research Board of Canada* 26: 479-541.

StatSoft 2001. STATISTICA for Windows. Tulsa, Oklahoma, U.S.A.

Williams, T. & B.C. Bedford 1974. The use of otoliths for age determination. Pp. 114-123 in: *The Ageing of Fish, Proceeding of an International Symposium*. Ed. by T. Bagenal. Unwin Brothers Limited, England.

Wootton, R.J. 1998. *Ecology of Teleost Fishes*. Kluwer Academic Publishers, Dordrecht, Netherlands. 386pp.

Zar, J.H. 1996. *Biostatistical analysis* (3rd edition). Prentice-Hall International. London. 662 pp.

Received 13 April 2012. Accepted 24 Sep 2012, Published online 12 December 2012.