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Growth, mortality and hatch-date distributions of striped sea bream *Lithognathus mormyrus* inhabiting the Çanakkale Strait, Turkey

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This paper studies age, growth and hatch date distributions of young of the year striped sea bream Lithognathus mormyrus *from Canakkale near shores by using a beach seine during September 2006–December 2007. Using otolith microstructure analysis, a total of 416 specimens ranging from 20 to 103 mm* L_T *were aged and found to be between 30 and 307 days old. Average growth rates were estimated to 0.325 mm* d^{-1}*. The juvenile instantaneous mortality coefficient was found to be 0.0219, which corresponds to a daily mortality of 2.16%. The hatching period of the striped sea bream was determined to occur between April and January, with relatively higher hatching frequency in August.*

Keywords: daily growth, mortality, hatch date, striped sea breem, *Lithognathus mormyrus.*

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INTRODUCTION

Otoliths are natural data loggers that record and store information on their microstructure at different spatiotemporal scales of growth and habitat interactions for fish (Kalish, 1989; Campana, 1999; Berg *et al.*, 2005). Otoliths provide information on growth, movement patterns and habitat interactions, which is essential in fisheries management. Age and growth information provides an integrated evaluation of environmental and endogenous conditions affecting a fish (Dervies & Frie, 1996). Otolith microincrements have been used to estimate the age of larval and juvenile fish (Jones, 1992; Campana, 2001).

Shallow waters are suitable as shelters and foraging sites for juvenile fish and as spawning grounds for adult fish (Ayvazian *et al.*, 1992). The survival of fish during early life stages have been estimated as a probable source of variability in recruitment to adult stocks (Hjort, 1914). In this period, survival rates are very low and it is very difficult to estimate catchable stock size. Young of the year (YOY) who survive early life stages are the most likely to recruit into the stock. It is essential to monitor growth and mortality rates of YOY in order to ensure ecologically and economically sustainable fishing.

The striped sea bream, *Lithognathus mormyrus* (Linnaeus, 1758) is a protandric hermaphrodite fish species belonging to the Sparidae family (Bessau, 1990; Besseau & Bruslesicard, 1991, 1995) It is a demersal fish species living in groups over various types of sea bottoms, especially sand, rocks and seagrass beds, at depths ranging from 0 to 150 m (Bauchot & Hureau, 1986, 1990). This species is distributed in the eastern Atlantic (from the Bay of Biscay to the Cape of Good Hope, and around the Canaries and Cape Verde) and the western Indian Ocean (from southern Mozambique to the Cape of Good Hope). It is also present in the Mediterranean, Black, Azov and Red Seas (Bauchot & Hureau, 1986, 1990; Harmelin-Vivien *et al.*, 1995).

The main spawning period of the striped sea bream from the Thracian Sea is between May and September, with a peak in June, July and August (Kallianiotis *et al.*, 2005). These results are in agreement with studies on striped sea bream on the Spanish Mediterranean coast (Suau, 1970). Maximum gonad activity has been reported by Lorenzo *et al.* (2002) in the central east Atlantic between August and September. In the Canaries archipelago, the spawning season of the striped seabream extends from June to November, with maximal gonadal activity occurring in August and September (Pajuelo *et al.*, 2002).

Striped sea bream (Sparidae) are commercially valuable and an important catch for the coastal and lagoon fisheries in Turkey (Emre *et al.*, 2010). This species has high commercial value, with commercial landings reaching 113.4 t in 2012, representing about 39.9% of total landings of striped sea bream from the Canakkale Strait (Tüik, 2012). Along the Turkish coasts, the striped sea bream is mainly caught by trammel nets, gill nets and longlines. In spite of its importance for the fisheries, the population dynamics of this species has never been described for the Canakkale Strait, Turkey.

Some biological aspects of adult *L. mormyrus* have been studied, such as age, growth, reproduction and mortality, in the northern and middle Adriatic Sea (Kraljevic *et al.*, 1995, 1996), in the Thracian Sea (Kallianiotis *et al.*, 2005), in eastern Spanish coastal waters (Suau, 1970), in the central–eastern Atlantic (Lorenzo *et al.*, 2002, Pajuelo *et al.*, 2002),

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on Sicilian coasts (Vitale *et al.*, 2011), in southern Portuguese coastal waters (Abecasis *et al.*, 2008, Monteiro *et al.*, 2010), in the Beymelek Lagoon (Emre *et al.*, 2010) and in Iskenderun Bay (Türkmen & Akyurt, 2003). Growth of juvenile striped sea bream on the Croatian Adriatic coast has been studied by assuming the hatching date as 1 July, and age in months was determined as the difference between the date of capture and the birth date (Matic-Skoko *et al.*, 2007). However, using an assumed hatching date may not provide accurate individual growth rate.

Therefore, the aim of this paper is to estimate the growth, mortality and hatching periods of the striped sea bream from Canakkale Strait, Turkey, using daily growth increments counts on sagittal otoliths. Seasonal changes in growth rates and the correlation between somatic growth and otolith growth will also be investigated.

MATERIALS AND METHODS

Fish were obtained from a survey originally designed to collect juvenile fish from nursery habitats of shallow waters ($<$2 m) in the Marmara Sea, the Dardanelles Strait and the northern Aegean Sea between September 2006 and December 2007 (Figure 1). All samples were collected in the daytime with a beach seine with a total wing length of 32 m, a height of 2 m and a 2 m long bag, with 13 mm mesh at the wings and 5 mm mesh at the bag. The hauls were made parallel to the shore, twice, haphazardly and non-overlapping. The surface water temperature was measured with a Hach Lange HQ40d probe during samplings.

A total of 938 YOY striped sea bream, *L. mormyrus*, ranging from 20 to 139 mm in total length (L_T) were collected during the 16 months in Canakkale shallow waters (Figure 2). Fish were killed with an overdose of quinaldine and stored in 70% alcohol. Total length (L_T) of the collected YOY striped sea bream was measured to the nearest 0.1 mm below and weighed to the nearest 0.01 g below. A total of 463 pairs of otoliths were removed, cleaned of adhering tissue, dried and stored in clean micro vials. From each pair, one otolith was randomly selected and mounted on glass slides with

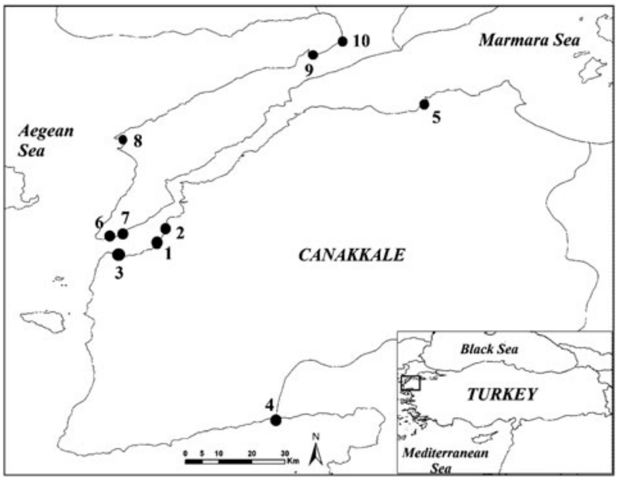

Fig. 1. Map of Canakkale coastline showing sampling stations of young of the year striped sea bream.

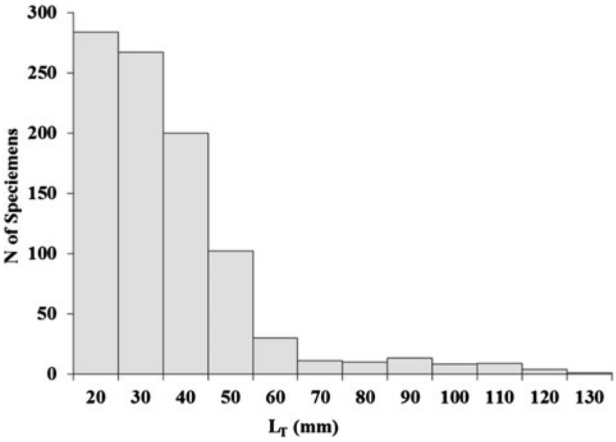

Fig. 2. Length–frequency distribution of young of the year striped seabream collected in the Canakkale shallow waters during the whole sampling period (September 2006 to December 2007). N = 938.

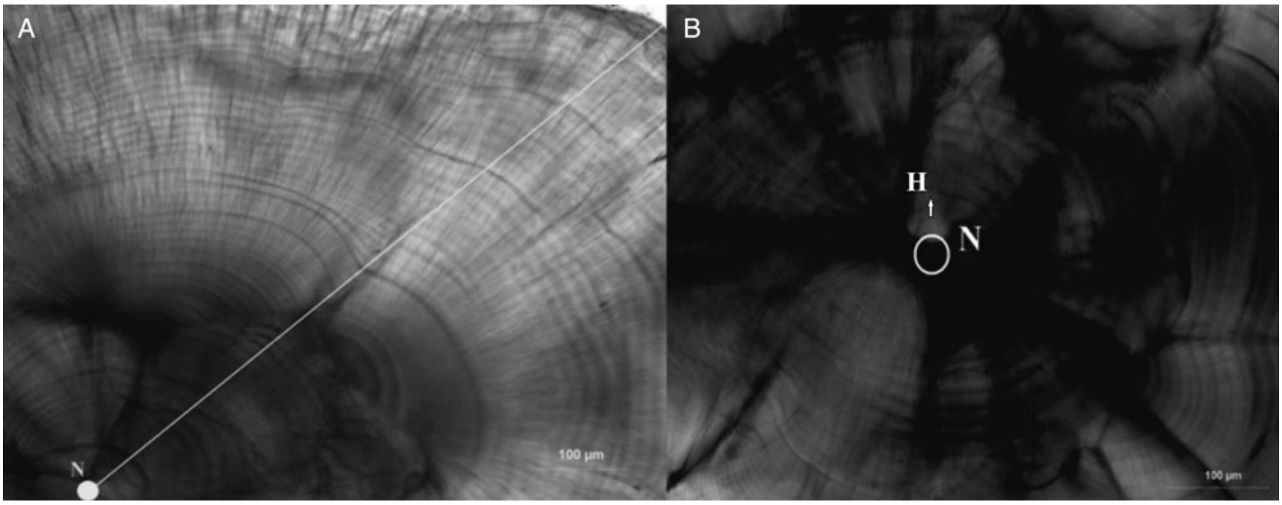

Fig. 3. Polished sagittal otolith of 39 mm L_T young of the year striped seabream aged 58 d; (A) growth increment counts were made from N (nucleus) to dorso-posterior axis (arrow); (B) circle shows nucleus and H is hatching check (arrow).

thermoplastic cement. Each otolith was polished with a series of abrasive papers of decreasing roughness, from 12 μm, to 9 μm, to 3 μm and finishing with 0.3 μm alumina paste on a polishing cloth, until daily rings were discernible from the centre to the edge (Miller & Storck, 1982; Secor *et al.*, 1991; Jones, 1992; Hayes, 1995). The process was checked frequently under a light microscope to avoid over-polishing the centre. An experienced reader counted the rings twice to ensure robustness of the analysis. Ring counts were done using a light microscope at 20 × , 40× or 100× magnifications.

Age was determined by counting the number of increments from a more prominent dark ring near the nucleus; this was assumed as the hatching check (Figure 3B) and increments were assumed to be formed daily. Although daily ring formation has not been validated for *L. mormyrus*, it has been widely demonstrated for many fish species (Pannella, 1971; Campana & Neilson, 1985). All increment counts could not take place along the same axis, but most of them took place in the dorso-posterior axis of the otolith (Figure 3A).

Otolith length (O_L), width (O_W) and radius (O_R) were measured to the nearest 0.001 mm below using Q Capture Imaging Software. O_L was defined as the longest axis between the anterior and the posterior otolith edge and O_W as the distance from the dorsal to the ventral edge taken perpendicular to the length through the otolith focus. O_R was measured as the longest axis between the nucleus and the posterior edge. The relationship between somatic growth and otolith growth was investigated by linear regression.

The relationship between fish size (L_T) and age (d) was assessed by linear regression, which corresponds to an average growth rate (mm d^{-1}). In order to determine seasonal changes of somatic growth rates, aged fish were grouped into cohorts based on hatch date. The significance of differences in growth equations among seasons was tested by analysis of covariance (ANCOVA).

For determination of the instantaneous mortality coefficient (Z), fish size was converted to age (d) according to the length–age relationships. Juvenile abundance was grouped into 5 d intervals. Estimates of Z were obtained using the age-based catch curve method of Ricker (1975). A linear regression analysis was computed to the ln-transformed data set, and the slopes of regression lines represented the instantaneous mortality coefficients. Daily mortality percentages (D_M) were expressed as:

$$D_M = (1 - \exp(-Z) * 100$$

The weight specific growth coefficient (G_T) was estimated as (Houde & Zastrow, 1993):

$$W_T = W_0^{GT},$$

where W_T is the weight (g) at time t (d), W_0 is the weight of juveniles in the previous age group in consideration, and G_T is the weight-specific growth coefficient. Changes in the M: G_T ratio have been suggested as a predictor of whether or not a cohort is increasing its biomass (Houde, 1996, 1997), where M is the instantaneous mortality rate and G_T is the weight-specific growth coefficient.

Hatch date distributions were back-calculated by subtracting the number of rings from the date of capture and plotting monthly intervals.

Table 1. Age–length key for young of the year *Lithognathus mormyrus*. N, total number of specimens per length/age group.

Length groups (mm)	Age groups (day)															
	20–39	40–59	60–79	80–99	100–119	120–139	140–159	160–179	180–199	200–219	220–239	240–259	260–279	280–299	300–319	N
20–24	7	25														32
25–29	10	60														70
30–34		59	8													67
35–39		22	40	6												68
40–44			18	26	7											51
45–49				9	30	13	1									53
50–54				3	7	14	4									28
55–59						2	10	1								13
60–64						1	4	3	1							9
65–69							3	2	1							6
70–74								1	3	1						5
75–79										2	1					3
80–84											2					2
85–89											3					3
90–94												3				3
95–99											1					1
100–104												1			1	2

RESULTS

A total of 416 specimens ranging from 20 to 103 mm L_T were aged, and age estimates ranged from 30 to 307 d (Table 1; Figure 3). The youngest fish (30 d) collected was 20 mm L_T and caught in August, while the oldest YOY (307 d) was 100 mm L_T and caught in July. The age group 40–59 d (20–39 mm) was the dominant age group (39.9%). Specimens of age groups 260–279 d and 280–299 d were absent. The first ring was observed at mean 14.39 μm (SE ± 0.408) from the core and it was assumed to be the hatching check (Figure 3B).

The different otolith length measurements (O_L, O_W, O_R) showed significant linear relationships with the fish length (L_T) (Figure 4; Table 2).

The growth rate of YOY striped sea bream was estimated by fitting a linear regression to the whole age–length data set (Figure 5). Length–age regression analysis resulted in growth rates of 0.325 mm d^{-1}. To test for seasonal changes in the growth rate of YOY striped sea bream, linear regressions were fitted to age–length data for larvae hatched during each of the four seasons, as defined by the hatch distribution.

Table 2. Parameters of the otolith length measurements (otolith length, OL; otolith width, OW; otolith radius, OR) linear relationships with the fish length (LT) of striped seabream from Canakkale Strait, Turkey. N is the number of specimens, a is the slope of the regression line, b is y-intercept and R2 is the coefficient of determination.

Otolith length measurements	N	*a*	*b*	R^2	*P*
O_L	391	24,11	−6,017	0,971	<0.01
O_W	391	46,01	−16,509	0,957	<0.01
O_R	104	39,35	−0,997	0,936	<0.01

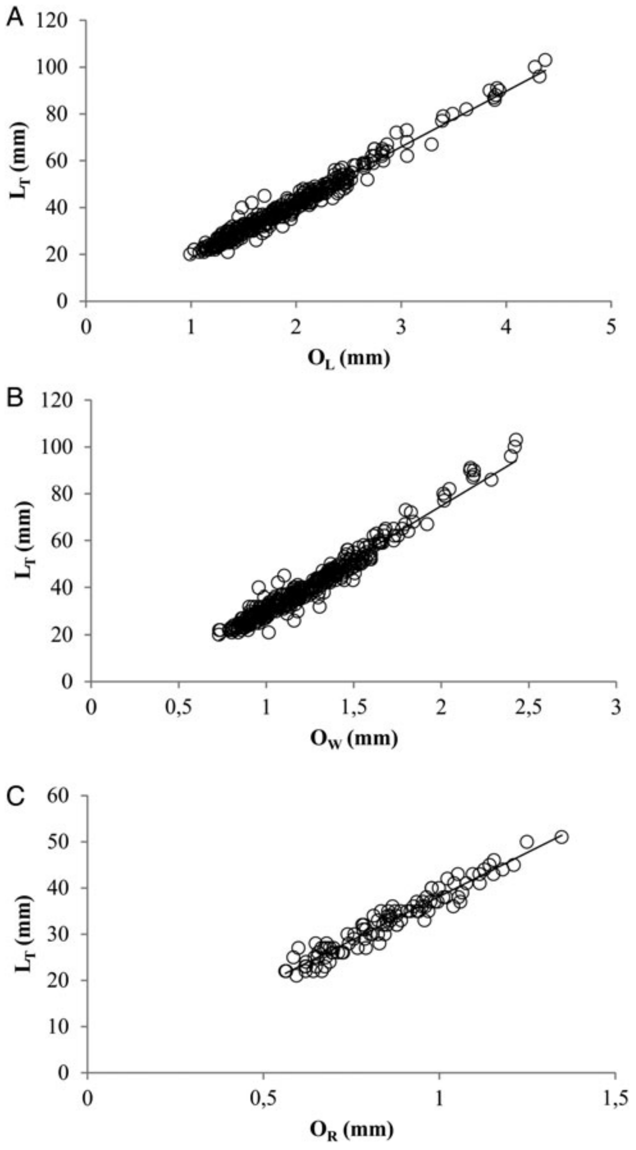

Fig. 4. Linear relationships between L_T (mm) and otolith length, O_L (A), otolith width, O_W (B) and otolith radius, O_R (C), of young of the year *Lithognathus mormyrus*.

According to the length–age regression analysis, maximum growth rates (G) were found 0.416 mm d^{-1} in the summer hatched cohort and minimum values of 0.312 mm d^{-1} were observed in the winter hatched cohort (Table 3). ANCOVA indicated that there was significant difference between the seasons ($P < 0.001$).

Relationships between YOY body weight (g) and age (da) were expressed as (Figure 6): $W = 0.0989e^{0.0222}$.

Data of natural logarithm of juvenile abundance were plotted against age, and the mortality coefficients were estimated as the slopes of these linear regressions (Figure 7). The juvenile instantaneous mortality coefficient was 0.0219, which represented around 2.16% of daily mortality.

The hatching period of the striped sea bream was estimated to occur between April and January, with relatively higher hatching frequency in August (Figure 8).

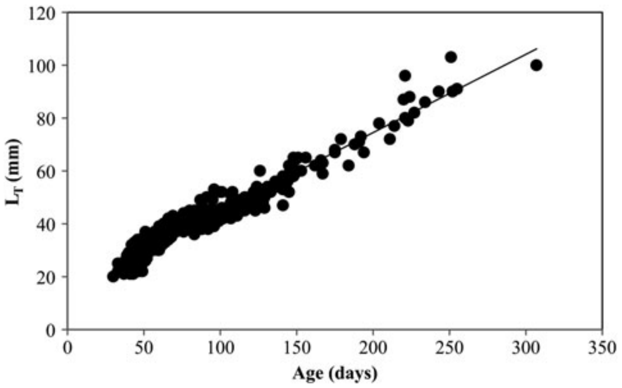

Fig. 5. Age–length relationship estimated for YOY *Lithognathus mormyrus* collected in the shallow waters of Canakkale Strait, Turkey.

Table 3. Parameters of the length-at-age linear relationships for different seasons of striped seabream in Canakkale Strait, Turkey. N is the number of speciemens, *a* is the slope of the regression line, *b* is *y*-intercept and R^2 is the coefficient of determination.

Season	N	*a*	*b*	R^2	*P*
Spring	5	10.796	0.374	0.992	0.017
Summer	205	9,98	0.416	0.872	<0.01
Autumn	130	11.601	0.317	0.974	<0.01
Winter	76	10.972	0.312	0.926	<0.01
Total	416	14.496	0.325	0.938	<0.01

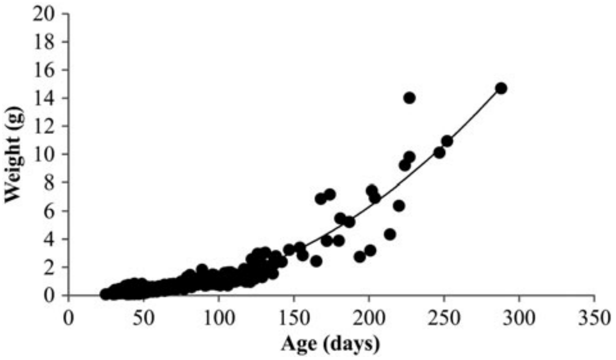

Fig. 6. Relationships of estimated age (d) and body weight (g).

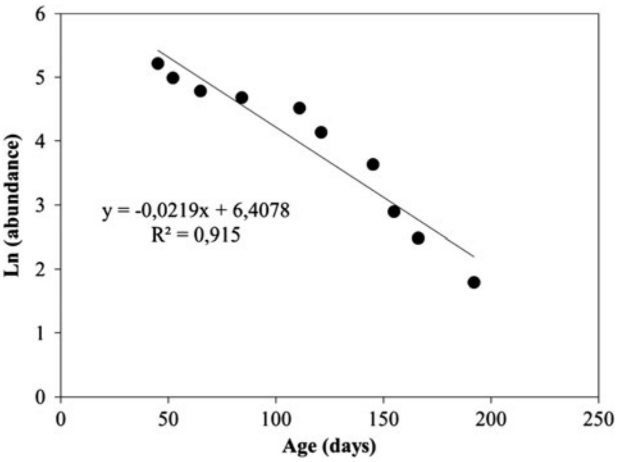

Fig. 7. Relationships of ln abundance at age.

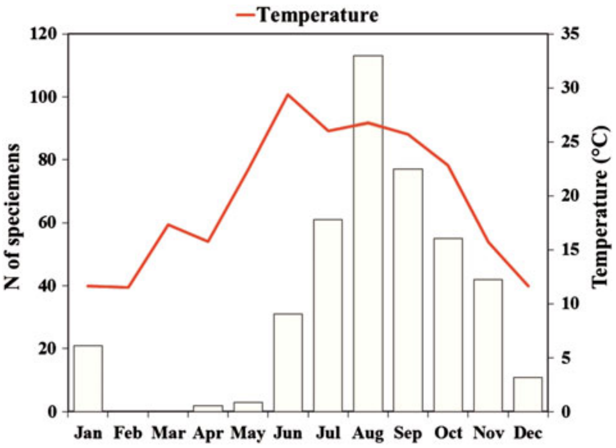

Fig. 8. Hatch date monthly distributions of young of the year *Lithognathus mormyrus* back-calculated from age estimates and date of capture with mean surface water temperature. The line corresponds to temperature and the boxes to numbers of larvae hatched.

DISCUSSION

The sagittal otoliths of the juvenile striped sea bream show distinct opaque and hyaline bands which can be used for age determination. In the absence of a validation study, the daily increment formation of striped sea bream otoliths cannot be confirmed. Otolith daily increment formation is a general phenomenon which has been validated for many species (Pannella, 1971; Brothers, 1978; Campana & Neilson, 1985; Geffen, 1987; Jones, 1992). In this study, otoliths of the striped sea bream showed a regular growth pattern with clearly identifiable increments (Figure 3). The youngest fish was estimated 30 d and caught in August, while the oldest YOY was 307 d and caught in July. A general decline in numbers was apparent as the fish got older (Table 1). Matic-Skoko *et al.* (2007), suggested that individuals were recruited at ~6–7 cm L_T, from shallow waters to deeper habitats. Therefore, the decline in the number of the older fish might partially be due to movements of the larger size fish to deeper waters.

The relationships between otolith and fish size reveal the ecological aspects of larval and juvenile fish. Two important relationships are used in fisheries: first, the allometric relationship between the otolith and fish size, and second, the individual growth rate of fish or population per day (Jones, 1992). The relationship between fish length and otolith radius of the larval stage of many species is allometric (Campana & Neilson, 1985; Thorrold & Williams, 1989; Jenkins & Davis, 1990) but in the juvenile stage isometric growth has been reported to be more common (Campana & Neilson, 1985). In this study the otolith length–fish length relationship was significantly linear, demonstrating that otolith growth was proportional to the growth of fish for *L. mormyrus*. This result showed that fish size can be estimated using the otolith size and also that individual growth patterns of juveniles back-calculated using the biological intercept method are reliable.

The microstructure of otoliths provides a major contribution to our understanding of growth in fish (Sponaugle, 2010). In the larval and juvenile stage period, the length and other morphological features of fish change very fast. In this regard, determination of daily growth in the sizes can be used to predict survival percentages of YOY individuals until they become mature (Houde, 1989). Growth is one of the most important factors for survival in larval and juvenile fish in early life stages. Faster-growing fish get past this period more quickly and thus have higher chances of survival (Takahashi & Watanabe, 2004). In this study, assuming a daily rate of increment formation, growth rates were found as 0.325 mm d^{-1}. There is no information about age and growth of YOY striped sea bream. So we compared the growth rates with similar species belonging to the same family. Growth rate estimates obtained from snapper, *Pagrus auratus,* gave 0.37 mm d^{-1} in Australia (Lenanton, 1974), 0.26 mm d^{-1} in New Zealand (Paul, 1976) and between 0.33 and 0.37 mm d^{-1} in Shijiki Bay, Japan (Kato *et al.*, 1991). From these results we can see that the growth rates of striped sea bream and snapper are quite similar.

Regarding the formation of daily rings, some authors have found that increments were not formed on a daily basis, and thus, that the age of the larvae were underestimated (Fox *et al.*, 2003). Environmental variations (e.g. temperature) can result in changes in actual growth rates (Campana, 1984). In some (unstable) environments such as the Baltic Sea, ring deposition can be halted due to slow growth, which makes ring counts unreliable for age estimations (less than one ring is formed per day) (Fox *et al.*, 2003). In this study, YOY striped sea bream growth rates have been found to be 0.416, 0.374, 0.317 and 0.312 mm d^{-1} for individuals who hatched in summer, spring, autumn and winter, respectively. The higher growth rates of the summer-hatched larvae are in correspondence with higher average temperatures (Figure 8). Matic-Skoko *et al.* (2007) reported that growth is directly and indirectly related to sea temperature fluctuations. Changes in environmental conditions (mainly temperature, salinity and food availability) in the different habitats may be connected with growth pattern (Wootton, 1990).

The estimated instantaneous mortality coefficient ($M =$ 0.0219) was almost equal to the weight-specific growth coefficient ($G_T =$ 0.0222), resulting in an M:G_T ratio of $<$1.0 (M:G_T ratio of 0.9864). Changes in the M:G_T ratio have been suggested as predictors of a cohort's biomass trend (Houde, 1997). Cohort biomass is declining when M:$G_T >$ 1.0 and is increasing when M:$G_T <$ 1.0 (Houde, 1997). This M:G_T ratio suggests that the YOY striped sea bream cohort biomass is increasing. Werner & Gilliam (1984) suggested that the M:G_T ratio is a powerful indicator of larval fitness.

In this study, the hatching period of the YOY striped sea bream was estimated to occur between April and January, with relatively higher hatching frequency in August. According to Wootton (1990), temperature is the most important environmental factor driving reproductive success in fish. The maximum hatching frequency in striped sea bream was in summertime where temperature is highest (Figure 9), perhaps indicating that hatching is correlated with, or influenced by, temperature. The differences of spawning period reported in different studies could be related to geographical area, sampling methods or estimation methods (e.g. GSI, ichthyoplankton and otolith microstructure).

These results are based on the assumption of daily increment formation, but the fact is that this has not been validated yet for the striped sea bream. A study investigating this should be conducted in order to ensure correct age and growth rate estimations. Such a study could be based on rearing larvae from hatching (Vigliola, 1997; Pajuelo & Lorenzo, 2011; Duffy *et al.*, 2012; Ellender *et al.*, 2012; Parkinson *et al.*, 2012; Dodson *et al.*, 2013; Farley *et al.*, 2013).

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REFERENCES

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

Ayvazian S., Deegan L. and Finn J. (1992) Comparison of habitat use by estuarine fish assemblages in the Acadian and Virginian zoogeographic provinces. *Estuaries and Coasts* 15, 368–383.

Bauchot M.L. and Hureau J.C. (1986) Sparidae. In Whitehead P.J.P., Bauchot M.L., Hureau J.C., Nielsen J. and Tortonese E. (eds) *Fishes of the north-eastern Atlantic and the Mediterranean, Volume II.* Paris: UNESCO, pp. 883–907.

Bauchot M.L. and Hureau J.C. (1990) Sparidae. In Quero J.C., Hureau J.C., Karrer C., Post A. and Saldanha L. (eds) *Check-list of the fishes of the eastern tropical Atlantic (CLOFETA).* Volume II: Lisbon and Paris: JNICT, SEI and UNESCO, pp. 790–812.

Berg E., Sarvas T.H., Harbitz A., Fevolden S.E. and Salberg A.B. (2005) Accuracy and precision in stock separation of north-east Arctic and Norwegian coastal cod by otoliths—comparing readings, image analyses and a genetic method. *Marine and Freshwater Research* 56, 753–762.

Brothers E.B. (1978) Exogenous factors and formation of daily and subdaily growth increments in fish otoliths. *American Zoologist* 18, 631–631.

Campana S.E. (1984) Interactive effects of age and environmental modifiers on the production of daily growth increments in otoliths of plainfin midshipman, *Porichthys notatus. Fishery Bulletin* 82, 165–177.

Campana S.E. (1999) Chemistry and composition of fish otoliths: pathways, mechanisms and applications. *Marine Ecology Progress Series* 188, 263–297.

Campana S.E. (2001) Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *Journal of Fish Biology* 59, 197–242.

Campana S.E. and Neilson J.D. (1985) Microstructure of fish otoliths. *Canadian Journal of Fisheries and Aquatic Sciences* 42, 1014–1032.

Dervies D.R. and Frie R.V. (1996) Determination of age and growth. In Murphy B.R. and Willis D.W. (eds) *Fisheries techniques.* Bethesda, MD: ASF, pp. 483–512.

Dodson J.J., Sirois P., Daigle G., Gaudin P. and Bardonnet A. (2013) Otolith microstructure during the early life-history stages of brown trout: validation and interpretation. *North American Journal of Fisheries Management* 33, 108–116.

Duffy W.J., McBride R.S., Hendricks M.L. and Oliveira K. (2012) Otolith age validation and growth estimation from oxytetracycline-marked and recaptured american shad. *Transactions of the American Fisheries Society* 141, 1664–1671.

Ellender B.R., Taylor G.C. and Weyl O.L.F. (2012) Validation of growth zone deposition rate in otoliths and scales of flathead mullet Mugil cephalus and freshwater mullet *Myxus capensis* from fish of known age. *African Journal of Marine Science* 34, 455–458.

Emre Y., Balik I., Sumer C., Oskay D.A. and Yesilcimen H.O. (2010) Age, growth, length–weight relationship and reproduction of the striped seabream (*Lithognathus mormyrus* L., 1758) (Sparidae) in the Beymelek Lagoon (Antalya, Turkey). *Turkish Journal of Zoology* 34, 93–100.

Farley J.H., Williams A.J., Clear N.P., Davies C.R. and Nicol S.J. (2013) Age estimation and validation for South Pacific albacore *Thunnus alalunga. Journal of Fish Biology* 82, 1523–1544.

Fox C.J., Folkvord A. and Geffen A.J. (2003) Otolith micro-increment formation in herring *Clupea harengus* larvae in relation to growth rate. *Marine Ecology Progress Series* 264, 83–94.

Geffen A.J. (1987) Methods of validating daily increment deposition in otoliths of larval fish. In Summerfelt R.C. and Hall G.E. (eds) *Age and growth of fish.* Ames, IA: Iowa State University Press, pp. 223–240.

Harmelin-Vivien M.L., Harmelin J.G. and Leboulleux V. (1995) Microhabitat requirements for settlement of juvenile sparid fishes on Mediterranean rocky shores. *Hydrobiologia* 300–301, 309–320.

Hayes J.W. (1995) Importance of stream versus early lake rearing for rainbow trout fry in Lake Alexandrina, South Island, New Zealand, determined from otolith daily growth patterns. *New Zealand Journal of Marine and Freshwater Research* 29, 409–420.

Hjort J. (1914) Fluctuations in the great fisheries of northern Europe, viewed in the light of biological research. *Rapports et Procès-Verbaux des Réunions du Conseil Permanent International pour l'Exploration de la Mer* 20, 1–228.

Houde E.D. (1989) Subtleties and episodes in the early life of fishes. *Journal of Fish Biology* 35 (Supplement A), 29–38.

Houde E.D. (1996) Evaluating stage-specific survival during the early life of fish. In Watanabe Y., Yamashita Y. and Oozeki Y. (eds) *Survival strategies in early life stages of marine resources.* Rotterdam: Balkema, pp. 51–66.

Houde E.D. (1997) Patterns and trends in larval-stage growth and mortality of teleost fish*. *Journal of Fish Biology* 51, 52–83.

Houde E.D. and Zastrow C.E. (1993) Ecosystem- and taxon-specific dynamic and energetics properties of larval fish assemblages. *Bulletin of Marine Science* 53, 290–335.

Jenkins G.P. and Davis T.L.O. (1990) Age, growth-rate, and growth trajectory determined from otolith microstructure of southern bluefin tuna *Thunnus maccoyii* larvae. *Marine Ecology Progress Series* 63, 93–104.

Jones C.M. (1992) Development and application of the otolith increment technique. In Stevenson D.K. and Campana S.E. (eds) *Otolith microstructure examination and analysis.* Ottawa, ON: Government of Canada Publications. [*Canadian Special Publication of Fisheries and Aquatic Sciences* Volume 117, pp. 1–11.]

Kalish J.M. (1989) Otolith microchemistry: validation of the effects of physiology, age and environment on otolith composition. *Journal of Experimental Marine Biology and Ecology* 132, 151–178.

Kallianiotis A., Torre M. and Argyri A. (2005) Age, growth, mortality, reproduction, and feeding habits of the striped seabream, *Lithognathus mormyrus* (Pisces: Sparidae), in the coastal waters of the Thracian Sea, Greece. *Scientia Marina* 69, 391–404.

Kato M., Sudo H., Azeta M. and Matsumiya Y. (1991) Field experiments of iridium marking for red sea bream in Shijiki Bay. *Bulletin of the National Research Institute of Far Seas Fisheries* 28, 21–45.

Kraljevic M., Dulcic J., Cetinic P. and Pallaoro A. (1996) Age, growth and mortality of the striped sea bream, *Lithognathus mormyrus* L, in the northern Adriatic. *Fisheries Research* 28, 361–370.

Kraljevic M., Dulcic J., Pallaoro A., Cetinic P. and Jugdujakovic J. (1995) Sexual-maturation, age and growth of striped sea bream, *Lithognathus mormyrus* L, on the eastern coast of the Adriatic sea. *Journal of Applied Ichthyology* 11, 1–8.

Lenanton R.C.J. (1974) The abundance and size composition of trawled juvenile snapper *Chrysophrys unicolor* (Quoy and Gaimard) from Cockburn Sound, Western Australia. *Australian Journal of Marine and Freshwater Research* 25, 281–285.

Lorenzo J.M., Pajuelo J.G., Mendez-Villamil M., Coca J. and Ramos A.G. (2002) Age, growth, reproduction and mortality of the striped seabream, *Lithognathus mormyrus* (Pisces, Sparidae), off the Canary Islands (Central-east Atlantic). *Journal of Applied Ichthyology* 18, 204–209.

Matic-Skoko S., Ferri J., Kraljevic M. and Dulcic J. (2007) Growth of juvenile striped seabream, *Lithognathus mormyrus* (Teleostei: Sparidae), in the Adriatic Sea. *Journal of Applied Ichthyology* 23, 286–287.

Miller S.J. and Storck T. (1982) Daily growth rings in otoliths of young-of-the-year largemouth bass. *Transactions of the American Fisheries Society* 111, 527–530.

Monteiro P., Bentes L., Coelho R., Correira C., Erzini K., Lino P.G., Ribeiro J., Gonçalves J.M.S. (2010) Age and growth, mortality and reproduction of the striped sea bream, *Lithognathus mormyrus* Linnaeus 1758, from the south coast of Portugal (Algarve). *Marine Biology Research* 6, 53–65.

Pajuelo J.G. and Lorenzo J.M. (2011) Validation of age determination methods and growth studies of the sand sole *Pegusa lascaris* (Soleidae) from the eastern-central Atlantic. *Ciencias Marinas* 37, 323–338.

Pajuelo J.G., Lorenzo J.M., Mendez M., Coca J. and Ramos A.G. (2002) Determination of age and growth of the striped seabream *Lithognathus mormyrus* (Sparidae) in the Canarian archipelago by otolith readings and backcalculation. *Scientia Marina* 66, 27–32.

Pannella G. (1971) Fish otoliths: daily growth layers and periodical patterns. *Science* 173, 1124–1127.

Parkinson K.L., Booth D.J. and Lee J.E. (2012) Validation of otolith daily increment formation for two temperate syngnathid fishes: the pipefishes *Stigmatopora argus* and *Stigmatopora nigra*. *Journal of Fish Biology* 80, 698–704.

Paul L.J. (1976) A study on age, growth, and population structure of the snapper, *Chrysophrys auratus* (Forster), in the Hauraki Gulf, New Zealand. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Bulletin* 13, 62.

Ricker W.E. (1975) Computation and interpretation of biological statistics of fish populations. *Fisheries Research Board of Canada Bulletin* 191, 382.

Secor D.H., Dean J.M. and Laban E.H. (1991) *Manual for otolith removal and preparation for microstructural examination*. Columbia, SC: Belle W. Baruch Institute for Marine Biology and Coastal Research.

Sponaugle S. (2010) Otolith microstructure reveals ecological and oceanographic processes important to ecosystem-based management. *Environmental Biology of Fishes* 89, 221–238.

Suau P. (1970) Contribution to knowledge of biology of *Lithognathus mormyrus* (Sparidae). *Investigación Pesquera* 34, 237–265.

Takahashi M. and Watanabe Y. (2004) Staging larval and early juvenile Japanese anchovy based on the degree of guanine deposition. *Journal of Fish Biology* 64, 262–267.

Thorrold S.R. and Williams D.M. (1989) Analysis of otolith microstructure to determine growth histories in larval cohorts of a tropical herring (*Herklotsichthys castelnaui*). *Canadian Journal of Fisheries and Aquatic Sciences* 46, 1615–1624.

Tüik (2012) TurkStat, Fishery Statistics. Available at: http://www.tuik.gov.tr/Kitap.do?metod=KitapDetay&KT_ID=13&KITAP_ID=52 (accessed 30 December 2013).

Türkmen M. and Akyurt I. (2003) Growth characteristics, sex inversion and mortality rates of striped sea bream, *Lithognathus mormyrus* L., in Iskenderun bay. *Turkish Journal of Zoology* 27, 323–329.

Vigliola L. (1997) Validation of daily increment formation in otoliths for three *Diplodus* species in the Mediterranean sea. *Journal of Fish Biology* 51, 349–360.

Vitale S., Arkhipkin A., Cannizzaro L. and Scalisi M. (2011) Life history traits of the striped seabream *Lithognathus mormyrus* (Pisces, Sparidae) from two coastal fishing grounds in the Strait of Sicily. *Journal of Applied Ichthyology* 27, 1086–1094.

Werner E.E. and Gilliam J.F. (1984) The ontogenetic niche and species interactions in size-structured populations. *Annual Review of Ecology and Systematics* 15, 393–425.

and

Wootton R.J. (1990) *Ecology of teleost fishes*. London, New York: Chapman and Hall.

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