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Age and growth of the black scorpionfish, *Scorpaena porcus* (Pisces: Scorpaenidae) from artificial structures and natural reefs in the Adriatic Sea

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SUMMARY: Age and growth of the black scorpionfish, *Scorpaena porcus*, were estimated for different populations inhabiting natural reefs and artificial structures (artificial reefs and offshore gas platforms) in the northwestern Adriatic Sea. Annual growth increment counts were carried out on sagittal otoliths of 415 specimens ranging from 80 to 280 mm TL. The accuracy of age estimates was assessed by testing the annual deposition of annuli and the location of the first annulus by marginal increment analysis and daily growth increment counts, respectively. As commonly observed in other scorpaenids, annuli consisted of an alternating pattern of opaque and translucent zones. Marginal increment analysis confirmed that annuli are formed once a year, with opaque zones laid down in spring-summer and translucent zones laid down in autumn-winter. The precision of age estimates was tested by applying both the average percent error (APE) and the mean coefficient of variation (CV). The maximum age estimated for the whole sampled populations was 8 years. The von Bertalanffy growth curves were separately fitted for natural and artificial reef populations of *S. porcus*. The likelihood ratio test indicated that the overall von Bertalanffy growth curves differed significantly between the two populations. The instantaneous growth rate (k, year^{-1}) and asymptotic length (L_∞, cm) were 0.23 and 22.30 and 0.53 and 20.13 for natural and artificial reef populations, respectively. Compared with natural reef population, populations of *S. porcus* inhabiting artificial reefs and, particularly, offshore platforms, were characterized by larger and older fish. However, young-of-the-year were completely absent from the platform habitats. The effects of artificial structures on *S. porcus* populations in the study area are discussed in the light of previous results on scorpionfish living in other areas.

Keywords: *Scorpaena porcus*, age and growth, natural reefs, artificial structures, Adriatic Sea.

RESUMEN: Edad y crecimiento del rascacio, *Scorpaena porcus* (Pisces: Scorpaenidae) en estructuras artificiales y arrecifes naturales en el mar Adriático. – Se estimó la edad y crecimiento del rascacio, *Scorpaena porcus,* de diferentes poblaciones de arrecifes naturales y estructuras artificiales (arrecifes artificiales y plataformas de gas a mar abierto) en el noroeste del mar Adriático. Los contajes de los incrementos de crecimiento anuales se realizaron en otolitos sagitta de 415 especímenes entre 80 y 280 mm de longitud total. La precisión de la estima de la edad se evaluó comprobando la formación anual de los anillos, y la localización del primer anillo mediante análisis de incrementos marginales y contajes de incrementos diarios, respectivamente. Tal como es comúnmente observado, los anillos presentan un patrón de zonas opacas y translúcidas que van alternando. El análisis de incrementos marginales confirmó que los anillos se forman una vez al año, con las zonas opacas que se depositan en primavera-verano y las translúcidas en otoño-invierno. La precisión en la estima de las edades se comprobó aplicando el porcentaje de error promedio y el coeficiente promedio de variación (CV). La edad máxima estimada para todas las poblaciones muestreadas fue de ocho años. Las curvas de crecimiento de von Bertalanffy growth se ajustaron separadamente para las poblaciones de *S. porcus* de arrecifes naturales y artificiales. El test de verosimilitud indicó que las curvas de crecimiento de von Bertalanffy diferían significativamente entre las dos poblaciones. La tasa instantánea de crecimiento (k, año^{-1}) y la longitud asintótica (L_∞, cm) fueron 0.23 y 22.30 y 0.53 y 20.13 para poblaciones de arrecifes naturales y artificiales, respectivamente. En comparación con las poblaciones de *S. porcus* de arrecifes naturales, las que se encuentran en arrecifes artificiales y, en particular en plataformas a mar abierto, se caracterizaron por peces más grandes y de más edad. No obstante, los individuos de edad inferior a un año están completamente ausentes en dichas plataformas. El efecto de estructuras artificiales en las poblaciones de *S. porcus* en el área de estudio se discuten en función de resultados previos de scorpeniformes de otras áreas.

Palabras clave: *Scorpaena porcus*, edad, crecimiento, arrecifes naturales, estructuras artificiales, mar Adriático.

INTRODUCTION

In the Mediterranean Sea, the genus *Scorpaena* is the most speciose group of scorpionfish, including six species, such as *Scorpaena elongata* Cadenat, 1943, *Scorpaena loppei* Cadenat, 1943, *Scorpaena maderensis* Valenciennes, 1833, *Scorpaena notata* Rafinesque, 1810, *Scorpaena porcus* Linnaeus, 1758, and *Scorpaena scrofa* Linnaeus, 1758 (Hureau and Litvinenko, 1986; Quignard and Tomasini, 2000). The genus consists of small- to medium-sized benthic fish (up to 50 cm TL), which are generally found on rocky, sandy or muddy bottoms from 20 to 800 m depth (Hureau and Litvinenko, 1986).

S. porcus, commonly known as the black scorpionfish, is one of the most common species, being distributed in the eastern Atlantic from the British Isles to Morocco and throughout the Mediterranean to the Black Sea. It is a benthic, sedentary littoral species of medium size (up to 25 cm), commonly found in inshore waters among rocks and seagrass beds (Hureau and Litvinenko, 1986). It is more active and spatially dispersed in search of food by night (Pashkov *et al.*, 1999), feeding mainly on benthic preys such as small fishes (gobies and blennies), crustaceans and other invertebrates (Bradai and Bouain, 1990; Pallaoro and Jardas, 1991; Carpentieri *et al.*, 2001; Morte *et al.*, 2001; Relini *et al.*, 2002; Silvestri *et al.*, 2002; Follesa *et al.*, 2004). Being sedentary, *S. porcus* is typically a sit-and-wait ambusher, feeding almost exclusively on motile prey (Harmelin-Vivien *et al.*, 1989).

The reproductive traits of *S. porcus* are fairly well known. Based on the annual cycle of gonadosomatic index and seasonal histology of gonads, the spawning of the black scorpionfish takes place between June and August in the western and central Mediterranean (Bradai and Bouain, 1991; Sàbat *et al.*, 2004), the Black Sea (Koca, 2002) and the Marmara Sea (Ünsal and Oral, 1996; Çelik and Bircan, 2004). Sexual maturity is reached at two and three years of age in males and females, respectively (Bradai and Bouain, 1991; Çelik and Bircan, 2004). Unlike oviparous fishes, ovaries of *S. porcus* show several peculiar characteristics, such as pedunculate oocytes, small and scarce cortical alveoli, a thin zona radiata and a gelatinous matrix secreted during the maturation (Sàbat *et al.*, 2004). Compared with other Mediterranean species of *Scorpaena* of larger size, such as *S. scrofa* and *S. elongata* (Bradai and Bouain, 1988; Ragonese *et al.*, 2003; La Mesa *et al.*, 2005), *S. porcus* is a slow-growing and short-lived fish, with a maximum life span of 11 years (Siblot-Boutaflika, 1976; Bradai and Bouain, 1988; Jardas and Pallaoro, 1992). Similarly, *S. porcus* attains 6 and 8 years of age in the Marmara Sea (Ünsal and Oral, 1996) and Black Sea (Koca, 2002; Bilgin and Çelik, 2008; Demirhan and Can, 2009), respectively.

In the northern Adriatic Sea, *S. porcus* is the most common scorpionfish in coastal waters. Despite the low commercial value mainly due to their small size, *S. porcus* play an important role in hard-bottom ecosystems, being one of the main species attracted by artificial structures such as artificial reefs and offshore gas platforms and by the rare rocky habitats of the Adriatic Sea (Bombace *et al.*, 1994; Fabi *et al.*, 2004). In the last twenty years many artificial reefs have been built throughout the Mediterranean, in order to enhance local fish populations and to improve small scale-fisheries as a consequence of fish attraction and/or production of new biomass. Indeed, several studies report high fish density, rapid colonization and high catch rates in areas where artificial reefs have been deployed (Bohnsack and Sutherland, 1985). This is more evident in areas far from natural hard substrates, where artificial reefs can provide additional food and shelter to mitigate predation, as in the case of the Adriatic Sea (Bombace, 1982; Bombace *et al.*, 1990, 1994; Fabi and Fiorentini, 1994).

In this study we report the age composition and growth rate of *S. porcus* estimated by otolith reading, applying indirect methods to evaluate the reliability (accuracy) and reproducibility (precision) of age estimates. A further aim was to test differences in growth parameters between populations of *S. porcus* sampled from natural and artificial reefs and to compare the growth performance of this species recorded in different areas of the Mediterranean Sea.

MATERIALS AND METHODS

Specimens of black scorpionfish (*S. porcus*) were collected in the northwestern Adriatic Sea between July 2004 and November 2008. The study area included both natural reefs consisting of hard substrates and artificial structures such as artificial reefs located in coastal waters and offshore gas platforms (Fig. 1). Natural and artificial reefs were located at about 0.5-3.0 nm from the coast, at a depth ranging from 8 to 15 m. Offshore gas platforms were located at 18-26 nm from the coast on a sandy-muddy bottom, at a depth ranging from 35 to 75 m. Roughly, each gas platform had a square base of 40x40 m, accounting for a total volume of approximately 15000 to 20000 m^3. Sampling was carried out in close proximity to natural reefs and artificial structures, using a beam trawl with 40 mm cod-end mesh size and trammel nets with 70 and 400 mm stretched mesh size (inner and outer panel, respectively). Hauls performed with beam trawl were randomly located over the whole sampling area. The beam trawl was generally towed at about 4.8-5.2 knots for 15-30 minutes on the bottom during daylight hours. Conversely, trammel nets were set at dusk and pulled in at dawn, for a mean time of 12 h. However, most catches (about 95%) were obtained by trammel nets.

In the laboratory, each specimen caught was measured as total length (TL) to the nearest mm below and weighed as total body weight (TW) with an accuracy of 0.1 g. Sex and stage of gonad development was assessed macroscopically following a five-point scale of maturity (Holden and Raitt, 1975). Both sagittal oto-

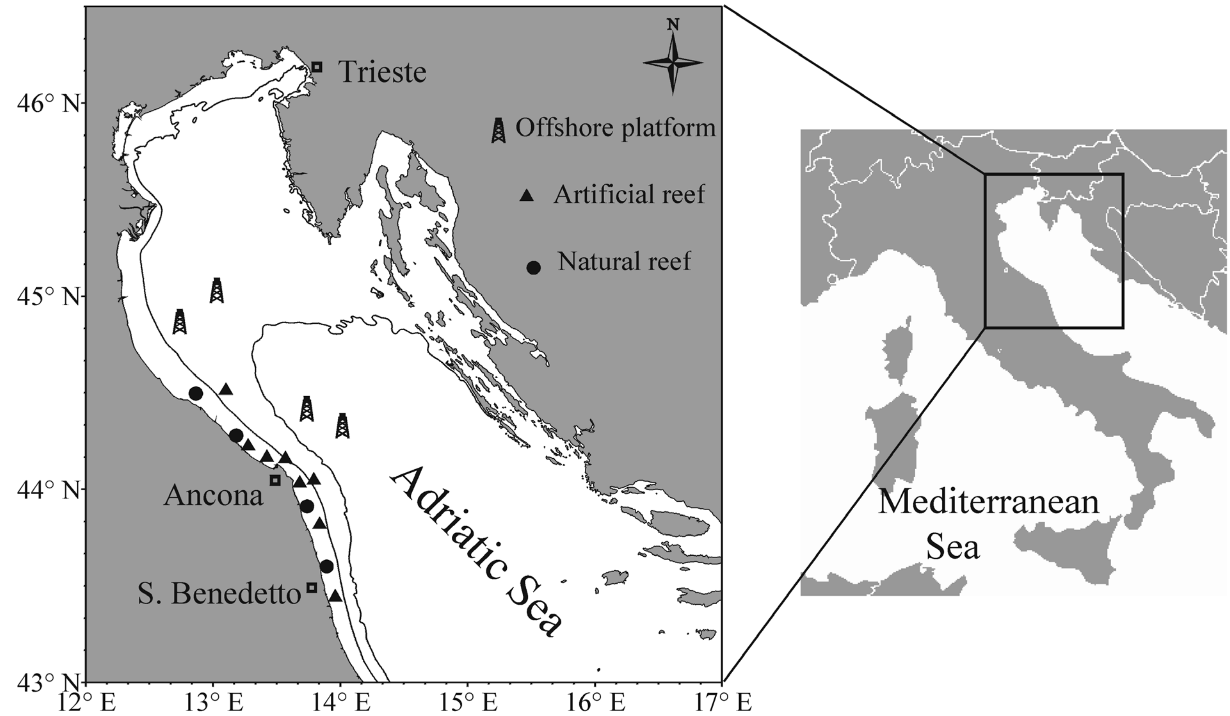

FIG. 1. – Map of northern Adriatic Sea with sampling locations of *Scorpaena porcus*. Solid lines indicate 20 m and 60 m depth.

liths were removed from each fish, cleaned and stored dry in numbered vials. Length-frequency distributions of *S. porcus* caught at natural and artificial reefs were compared with each other using the two-sample Kolmogorov-Smirnov test (Sokal and Rohlf, 1995).

The weight (OW), with an accuracy of 0.1 mg, and the maximum length (OL), with an accuracy of 0.1 mm, of each otolith pair were initially recorded and compared applying a *t* test for paired comparisons (Sokal and Rohlf, 1995). As no statistically significant difference was found between left and right otoliths (Student's *t* test: df = 378, $P>0.05$ in both cases), we arbitrarily selected right otoliths for measurements. All measurements were conducted under a stereomicroscope using an image analysis software (Image-Pro Plus, vers. 4.5.1 Media Cybernetics). The relationships between fish size (TL) and otolith size (OL) and weight (OW) were estimated by applying linear regression analysis on $\log_{10}$-transformed data, in order to correct for nonlinearity and heterogeneity of variances.

Otolith samples were fully immersed in ethanol and observed under a stereomicroscope at 25-40× magnification. Under reflected light, the nucleus and the opaque zones appeared as light rings and the translucent or hyaline zones as dark rings (Fig. 2). This pattern was quite clear also viewing the whole otolith, and therefore did not require sectioning and grinding techniques to reveal it. The combination of each opaque and subsequent translucent zone was considered to form an annulus, as observed in other scorpaenids (Massutí *et al*., 2000; López Abellán *et al*., 2001; La Mesa *et al*., 2005). Commonly, the annuli were formed by wide opaque zones and narrow translucent zones. The count path showing the most unambiguous annulation pattern was generally from the nucleus towards the tip of rostrum, where the deposition of seasonal rings appeared to start. The width of each annulus was measured on this axis, with an accuracy of 0.01 mm.

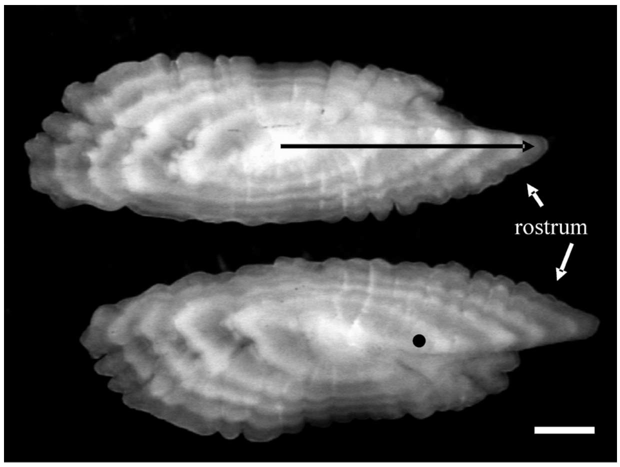

FIG. 2. – Photomicrograph of the sagittal otolith of *Scorpaena porcus*, showing the annulation pattern in a five-year-old female. Scale bar = 1 mm; first annulus (*black dot*); reading/measurement radius (*black arrow*).

Each otolith was read by one reader, without any ancillary data on fish size. A second reading was carried out a week later by the same reader. When readings differed by one or more years, a third reading was made; if the difference still occurred, the otolith was discarded. The index of average percent error (APE)

(Beamish and Fournier, 1981) and the mean coefficient of variation (CV) (Chang, 1982) were calculated to estimate the relative precision between readings.

To validate seasonality of deposition of opaque and translucent zones, the marginal increment analysis was carried out on the entire otolith sample (Beckman and Wilson, 1995; Panfili and Morales-Nin, 2002). Since the spawning season of *S. porcus* is between June and August (Bradai and Bouain, 1991; Sàbat *et al.*, 2004), we considered 1 July as the birthdate of the species. We observed that the opaque nucleus was deposited during the first summer after hatching, followed by the first translucent zone laid down in the following winter just prior to the first birthday. Assuming that the annuli were laid down yearly, the age of fish was estimated by counting all the translucent zones. The final age of each fish was then estimated in months on the basis of the date of capture.

To validate specimens aged 0, i.e. fish with sagittae composed of only an opaque nucleus, some otoliths were prepared for counting of microincrements, assuming they are laid down daily (Laidig and Ralston, 1995; Furlani, 1997; Massutí *et al.*, 2000). Otoliths were set in moulds, embedded in epoxy resin and ground until the sagittal plane was reached. They were polished with 0.05 μm alumina paste and the microincrements were counted under a light microscope at 400× and 630× magnification. The von Bertalanffy growth function was fitted to the estimated age-length data set using the FISHPARM program of the FSAS statistical package (Saila *et al.*, 1988), applying the Marquardt algorithm for non-linear least squares parameter estimation. The von Bertalanffy growth parameters (L_∞, k and t_0) were calculated for each population sampled in natural and artificial reefs, respectively, and compared by the likelihood ratio test (Kimura, 1980). The growth performance index ($\Phi' = 2 \log L_\infty + \log k$) (Munro and Pauly, 1983) was then calculated to compare the different populations of *S. porcus* throughout the Mediterranean Sea.

Similarly, the length-weight relationship of fish was calculated separately for the natural reefs, artificial reefs and platform populations by fitting the exponential equation $TW = a\ TL^{b}$, and the allometric indices (b) were compared by applying an F test (Sokal and Rohlf, 1995).

RESULTS

Length-frequency distribution

The length-frequency distributions of *S. porcus* populations caught from natural reefs (NR), artificial reefs (AR) and platforms (PL) are summarized in Figure 3. Overall, 134 specimens of 110-221 mm TL were caught at the NR, 210 specimens of 80-270 mm TL were caught at the AR and 71 specimens of 135-280 mm TL were caught at the PL. All comparisons between length-frequency distributions were statistically different (Kolmogorov-Smirnov test, n_1 = 134 and n_2 = 210, P<0.01; n_1 = 134 and n_2 = 71, P<0.01; n_1 = 210 and n_2 = 71, P<0.01). Indeed, the proportion of larger fish increased significantly in the AR and PL populations compared with the NR population. On the other hand, the sex ratio was not significantly different from unity in all populations (test χ^2, df = 1, P>0.01, P>0.1, P>0.5, respectively).

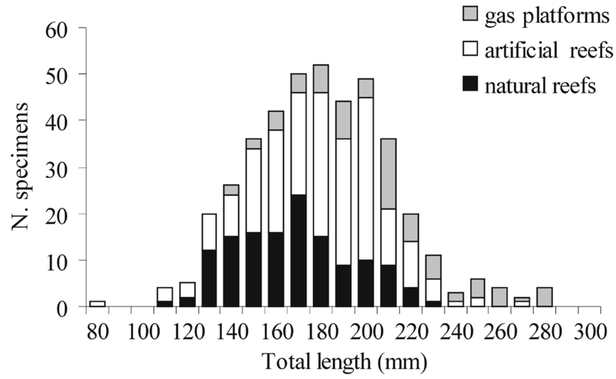

Fig. 3. – Length-frequency distribution of *Scorpaena porcus* from the northwestern Adriatic Sea.

Annulation pattern

The inner structure of sagittal otoliths of *S. porcus* consisted of a wide opaque nucleus, surrounded by an alternating pattern of translucent and opaque zones of comparable width. The width of the first annulus, composed of nucleus plus the first translucent zone, was quite different among fish, whereas subsequent annuli were more regular. From the second annulus onwards, translucent and opaque zones showed a slow decrease in thickness, getting progressively narrower (Fig. 4).

Maximum otolith length (OL) and otolith weight (OW) ranged between 4.57 and 10.83 mm and 4.9 and 50.2 mg, respectively. The relationship between OL (mm) and TL (mm) was linear and negatively allometric (b = 0.77, SE = 0.0019; t test, P<0.01) (Fig. 5a). Instead, the relationship between OW and TL was

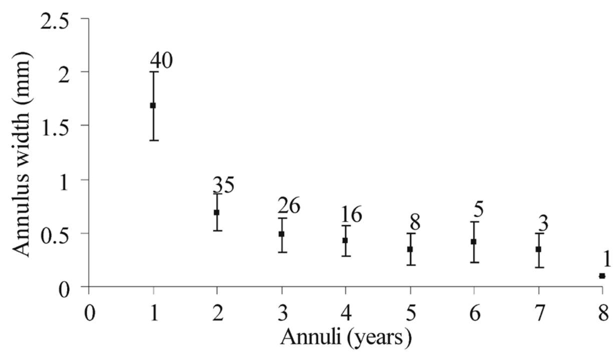

Fig. 4. – Average width of annuli observed in sagittal otoliths of *Scorpaena porcus*. Bars indicate standard deviations; number of specimens of each age class is indicated above bars.

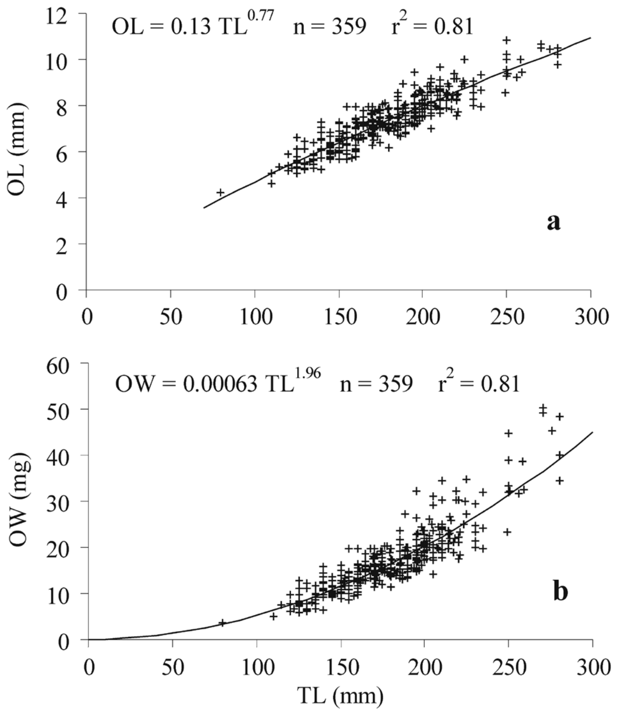

FIG. 5. – Scatter plots and fitted regression lines of maximum otolith length (OL) (a) and otolith weight (OW) (b) versus fish length (TL).

curvilinear (Fig. 5b).

Age estimates, accuracy and precision

The age composition estimated for each population caught at the NR, AR and PL is summarized in the age-length keys (Table 1). Though age range and longevity

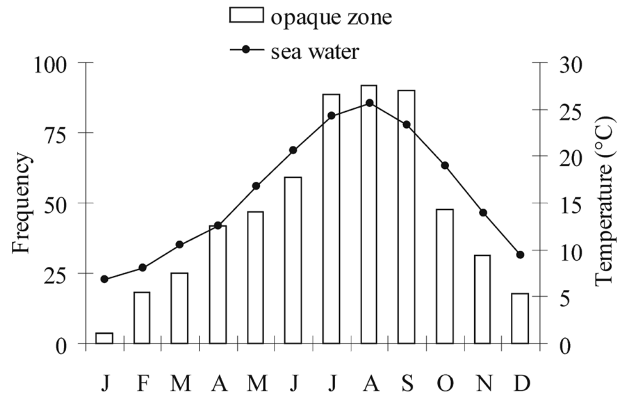

FIG. 6. – Monthly change in relative frequency of opaque zone on otolith edge of *Scorpaena porcus* and sea bottom temperature.

were comparable among the different populations of *S. porcus*, the proportion of older (and larger) fish increased significantly from the NR through AR and PL. In the NR, most fish (96%) were estimated to be 0-4 years old, with a maximum age of 7 years. In the AR, 97% of aged specimens were between 0 and 5 years, with a maximum age of 8 years. In the PL, only one specimen was younger than 2 years, whereas 94% of fish were aged between 2 and 7 years.

The annual periodicity of annulus deposition was supported by the marginal increment analysis, indicating that each pair of translucent and opaque zones was formed once a year. The opaque zone was laid down from February to August, while the translucent zone was laid down from September to January (Fig. 6). Interestingly, the seasonal trend of the opaque zone formation closely resembled the pattern of sea-bottom temperature recorded by a CTD deployed monthly on

TABLE 1. – Age-length keys of *Scorpaena porcus* from natural reefs and artificial structures in the Adriatic Sea.

	Age (years)																										
	natural reefs									artificial reefs									platforms								
TL (mm)	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8
80										1																	
90																											
100																											
110	1									2	1																
120		3								1	2																
130	4	4	3							2	3	4															
140	1	4	6	3	1					1	2	2	3							1	1						
150	1	6	8	1							5	10	3	2							2	3					
160		1	7	6	2						6	7	8	2							1	2	1				
170			9	12	4							4	13	9								2	1				
180			4	7	2		1				1	6	9	8		1	1					3	2	1			
190			2	4	3							6	10	7	3			1				3	3				
200			2	6	4							6	13	10	6	1						1	4	3			
210			2	2	2	2		1					6	3	1		1				1	2	5	3			
220			1		1			1					4	3	2							1	2	2	3		
230													2		1	1								2	1		
240														1								1	1				
250														1	1								1	1	2	1	
260																										2	1
270															1										1		
280																										2	2
n	7	18	44	41	19	2	1	2		7	20	45	71	46	15	3	2	1		1	5	18	20	12	7	5	3
%	5	13	32	30	14	2	1	2		3	10	21	33	21	7	2	2	1		1	7	26	28	17	10	7	4

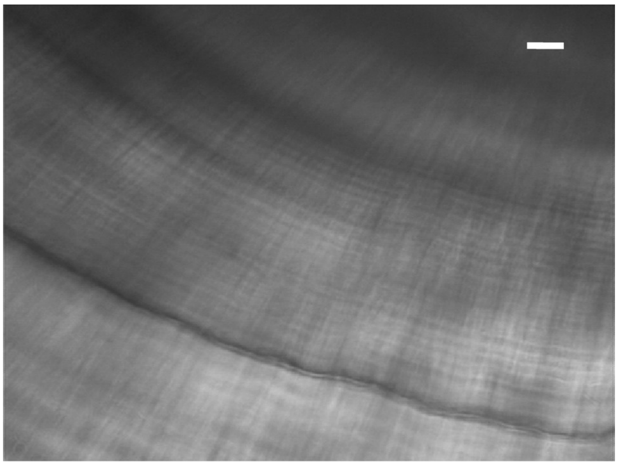

FIG. 7. – Photomicrograph of otolith microstructure in the core region, showing the typical pattern of alternating light and dark increments assumed to be deposited daily. Scale bar = 10 μm.

each area during the sampling period.

The microincrement counts to validate fish aged 0 (i.e. young of the year) on the basis of annuli were carried out on five specimens ranging between 80 and 135 mm TL. The otolith microstructure showed the typical pattern of light and dark alternated increments, representing daily growth rings (Fig. 7). A continuous series of concentric rings of increasing size ranging from 1.2 to 2.8 μm was observed from the core to the otolith margin. Age estimates were from 240 to 350 days, thus validating specimens aged 0, namely those with sagittae with an opaque nucleus and a more or less developed translucent zone.

The reliability of criteria used for ageing *S. porcus* was supported by the relatively high precision of age readings. Counting variability indices APE and CV were both quite low (9.8 and 13.9%, respectively), with a percentage agreement between readings of 56%, indicating a reasonable consistency (or reproducibility) between readings. Only 5.8% of readings differed by more than 1 year, with a maximum disagreement of 3 years.

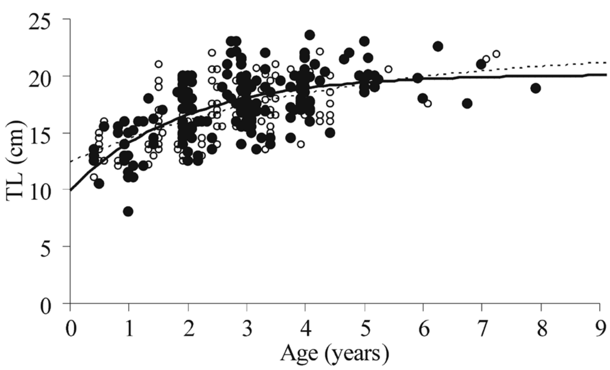

FIG. 8. – Plot of age-length data pairs and fitted von Bertalanffy growth curves for natural reef populations (open circles, dotted line) and artificial reef populations (full circles, solid line) of *Scorpaena porcus* from the northwestern Adriatic Sea.

TABLE 2. – Estimates of Von Bertalanffy growth parameters and growth performance of *Scorpaena porcus* from natural and artificial reefs in the Adriatic Sea

Parameter	natural reefs	artificial reefs
L_∞ (cm)	22.30 (0.73)	20.13 (2.95)
K (cm^{-1})	0.23 (0.13)	0.53 (0.12)
t_0 (year)	-3.43 (0.48)	-1.29 (1.37)
Φ’	2.07	2.33
n	134	207

n, sample size; asymptotic standard errors are in brackets

TABLE 3. – Estimates of length-at-age and annual growth for *Scorpaena porcus* from natural reefs (NR) and artificial reefs (AR) in the Adriatic Sea

Age (years)	Length-at-age (cm)		Annual growth (cm)	
	NR	AR	NR	AR
0	10.0	12.4		
1	14.1	14.4	4.1	2.2
2	16.6	16.1	2.5	1.7
3	18.1	17.4	1.5	1.3
4	18.9	18.4	0.8	1.0
5	19.4	19.2	0.5	0.8
6	19.7	19.9	0.3	0.7
7	19.9	20.4	0.2	0.5
8	20.0	20.8	0.1	0.4

Growth rate

In order to compare growth rate of populations from different areas, the von Bertalanffy growth curves were fitted to age-length data pairs estimated from natural and artificial reefs (Fig. 8), pooling data for both sexes and taking into account the same size range. Due to the small sample size, no growth curve was fitted to the population sampled off platforms. von Bertalanffy growth parameters and the derived growth performance index (Φ’) are reported in Table 2. The likelihood ratio test indicated that the overall von Bertalanffy growth curves differed significantly between the two populations tested (χ^2, df = 3, P<0.05), as well as combining the two parameters L_∞ and k (χ^2, df = 2, P<0.05). Instead, no statistical difference in length-at-age data (Table 3) derived from the von Bertalanffy growth curves was observed between the two populations (t test for paired comparison, df = 8, P>0.5). In both populations, the annual growth rate was relatively high until they reach three years of age, i.e. at the attainment of the sexual maturity, becoming very low thereafter.

Fish length-weight relationship

The length-weight relationships of fish calculated for each of the populations caught at the NR, AR and PL are shown in Figure 9. In no relationships the slopes (NR, b = 2.94, SE = 0.061; AR, b = 3.03, SE = 0.046; PL, b = 3.12, SE = 0.069) were significantly different from 3.00 (t test for allometry, P>0.05 in any case), indicating a common isometric growth. Applying an F test, no difference was found between the allometric

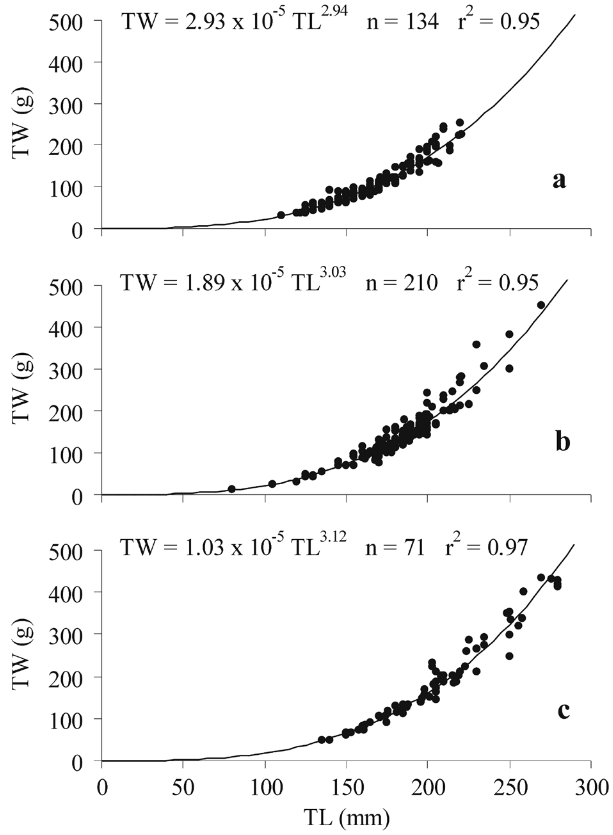

FIG. 9. – Relationships between fish length (TL) and weight (TW) for populations sampled on natural reefs (a), artificial reefs (b) and platforms (c) in the northwestern Adriatic Sea.

coefficients (*b*) calculated for population sampled at the AR and NR ($F_{1,\,331}$, P>0.1) and at the AR and PL ($F_{1,\,268}$, P>0.1). Instead, the allometric coefficient was significantly different between the NR and PL populations ($F_{1,\,201}$, P<0.05).

DISCUSSION

Scorpaenids are characterized by having relatively large otoliths (Tuset *et al.*, 2008), which makes them easy to handle for ageing purposes. The inner structure of sagittal otoliths of *S. porcus* closely resembled those observed in other scorpaenids, with alternating patterns of translucent and opaque zones around an opaque nucleus. However, unlike other scorpaenid fish genera such as *Helicolenus* and *Pontinus* (Massutí *et al.*, 2000; López Abellán *et al.*, 2001), in *S. porcus* each translucent and subsequent opaque zone had the same width as each other, although their thickness slowly decreased towards the otolith margin. A similar pattern was also observed in sagittal otoliths of *Scorpaena maderensis* (La Mesa *et al.*, 2005).

Consistent with many other scorpaenids, such as *H. dactylopterus* (Massutí *et al.*, 2000), *Scorpaena guttata* (Love *et al.*, 1987), *S. maderensis* (La Mesa *et al.*, 2005) and *Sebastes* spp. (Love *et al.*, 1990), the present results showed that annuli in sagittal otoliths of *S. porcus* are laid down annually, the opaque zone being generally deposited in spring-summer and the translucent zone in autumn-winter (Morales-Nin, 2001). Moreover, the great consistency among repeated age readings makes otoliths the most reliable hard part for ageing scorpaenid fish.

Several studies concerning age and growth of *S. porcus* are currently available across their geographical distribution (Table 4). The estimated life span of this species is generally 6-7 years of age and is very similar among populations from different areas, except for the population inhabiting the northeastern sector of the Adriatic Sea (Table 4). Interestingly, a striking difference in life span seems to occur between northeastern and northwestern Adriatic populations of *S. porcus* (Jardas and Pallaoro, 1992; present data), possibly related to different environmental conditions and/or different fishing pressure. As far as growth parameters are concerned, there is a good agreement between the maximum attainable sizes (i.e. asymptotic length, L_∞) and instantaneous growth rates (k) estimated from different populations, as well as the derived growth performance index (Φ') (Table 4). On the other hand, the Black Sea population of *S. porcus* seems to be able to attain a larger maximum size at a lower growth rate (Koca, 2002). In two most recent studies from the Black Sea, the von Bertalanffy growth function did not adequately model the growth of *S. porcus*, providing an unreliable estimate of asymptotic length (Bilgin and Çelik, 2008; Demirhan and Can, 2009).

Despite the wide increasing distribution of artificial reefs over the past century, intentionally deployed on the seafloor to increase the abundance of commercially and recreationally important fish species (Brickhill *et al.*, 2005), little is known about the comparative ecological performance of fishes associated with artificial habitats compared to those inhabiting natural habitats (Carr and Hixon, 1997). A pilot study showed that young-of-the-year blue rockfish (genus *Sebastes*) grew faster at an offshore oil platform than at a natural out-

TABLE 4. – Estimates of Von Bertalanffy growth parameters and age range for *Scorpaena porcus* from different areas. Φ' = growth performance index

L_∞ (cm)	K (year^{-1})	t_0 (year)	Φ'	Age (years)	Area	Source
32.4	0.18	-0.93	2.28	-	Ligurian Sea	Silvestri *et al*. (2002)
28.2	0.18	-0.80	2.16	1-11	Adriatic Sea	Jardas and Pallaoro (1992)
23.1	0.16	-0.85	1.93	1-6	Gulf of Gabes	Bradai and Bouain (1988)
29.3	0.16	0.97	2.14	1-7	Algerian Sea	Siblot-Boutaflika (1976)
24.4	0.16	-1.19	1.98	1-7	Marmara Sea	Ünsal and Oral (1996)
40.8	0.11	-2.23	2.26	1-6	Black Sea	Koca (2002)

crop, indicating that juvenile fishes at platforms are at least as healthy as those around natural outcrops (Love *et al*., 2007). Without entering into the ongoing attraction versus production debate to explain the increased fish abundance on artificial reefs (Brickhill *et al*., 2005), the effects of artificial structures on the black scorpionfish were particularly evident in the northwestern Adriatic Sea, where they were far from natural hard substrates and totally encircled by sandy or muddy bottoms. There, soon after artificial reef deployment, fish abundance, species richness and diversity gradually increased, especially as a consequence of the increase in hard-substrate species (such as sciaenids and scorpaenids), which were rare or absent in the original natural soft bottom habitat (Bombace *et al*., 1994).

Other than an increased fish abundance as a positive outcome, artificial structures located in the study area seem to benefit *S. porcus* populations in terms of maximum size, growth performance and longevity. This was true mainly for the population inhabiting areas around offshore gas platforms. The platform bases appear to be important to several fish species (Love *et al*., 2007), as they provide both refuge and prey especially for those species with cryptobenthic habits, like rockfishes or scorpionfishes. These fish often exhibit variegated colour patterns that blend well with their surroundings, thus enabling them to remain undetected by their prey. In addition, platforms usually harboured higher densities of young-of-the-year rockfishes than natural outcrops and thus may be functionally more important as nurseries (Love *et al*., 2003).

Instead, the population of *S. porcus* sampled around offshore platforms in the northwestern Adriatic Sea consisted almost exclusively of large fish older than two years. Two opposing but not mutually exclusive hypotheses might be proposed to explain this finding. Young-of-the-year of black scorpionfish inhabit preferentially platform midwaters, as reported in rockfishes off California (Love *et al*., 2003), avoiding being caught by trammel net set on the sea bottom or beam trawling. Alternatively, young-of-the-year are actually absent around offshore platforms because spawning (and nursery) areas of the species are located in coastal waters. Indeed, early life stages of scorpaenids are generally more concentrated in coastal than offshore waters in the western Mediterranean (Crec'hriou *et al*., 2008). In addition, the black scorpionfish larvae are pelagic for a relatively short time (i.e. just a month) before settlement (Raventós and Macpherson, 2001), and therefore find it difficult or impossible to reach offshore platforms and settle in their proximity. As a consequence, the population of *S. porcus* living around offshore platforms might be sustained by individuals settled inshore. Though more scorpaenids are rather sedentary, movement of more than 200 km has been demonstrated for the California scorpionfish, *Scorpaena guttata*, which seems to be able to move freely through midwater and travel long distances, presumably to spawn (Hartmann, 1987).

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