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Age structure of spawners of the axillary seabream, *Pagellus acarne* (Risso, 1827), in the central Mediterranean Sea (Strait of Sicily)

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ABSTRACT

An unusual catch of mature specimens *of Pagellus acarne* (Risso, 1827) off the south coast of Sicily (Quadro Bank, central Mediterranean Sea) on October 2016 allowed to improve the ongoing knowledge on the age structure of spawners and other reproductive aspects of the species. A sample of 104 (32 female and 72 male) specimens was examined. Females showed size (range TL[1] = 20.5 to 25.5 cm; mean length = 22.3 ± 1.2 cm) longer than males (range TL = 16.5 – 23.5 cm; mean length = 20.0 ± 1.8 cm). About 94% of females and 88% of males were mature. The pooled sex LWR[2] was W[3] (g) = 0.003 $TL^{3.5207}$. The age structure estimated by *sagittae* readings ranged from age class III to VII in females and II to VI in males with a prevalence of age class VI and IV for females and males, respectively. The precision of age estimates was tested by applying both the APE[4] and the mean CV[5].

Our record suggests that the Quadro Bank is an EFH[6] for *P. acarne*. Knowing when and where adults aggregate for reproduction, is a prerequisite to develop effective management measures to preserve the replacement capability of exploited stocks and pursue sustainable fisheries strategies.

1. Introduction

Overall, species belonging to the family of Sparidae constitute an important fishery resources in warm temperate marine areas such as the Mediterranean Sea (e.g. Gordoa and Molì, 1997; Monteiro et al., 2010; Marengo et al., 2016) in terms of species diversity, total landing and high commercial value of the landings (Mouine et al., 2012). Among the Sparidae, the genus *Pagellus* includes several species targeted by Mediterranean demersal fisheries, being the most important the axillary seabream, *P. acarne* (Risso, 1827), the blackspot seabream, *P. bogaraveo* (Brünnich, 1756) and the common pandora, *P. erythrinus* (Linnaeus, 1758).

In particular, *P. acarne* shows a wide geographical distribution along the northern and eastern Atlantic coasts from Norway to Senegal and around the Macaronesia Island, as well as the Mediterranean Sea (Russell et al., 2014). The species inhabits mainly areas with sandy and muddy soft bottoms down to 500 m depth, although it is more common between 40 and 100 m with juveniles often frequently found on *Posidonia oceanica* (Delile, 1813) beds near the shore (Bauchot and Hureau, 1986; Parenti and Poly, 2004; Coelho et al., 2005).

Axillary seabream is one of the main target species of small-scale commercial fisheries in the northern Atlantic Algarve (Erzini et al., 2001), Azores (Morato et al., 2001) and Canary Islands (Pajuelo and Lorenzo, 1994, 2000). In the Mediterranean Sea, it is mostly a by-catch of both artisanal vessels and trawlers. The status of the stocks in the region is almost unknown with the exception of the Alboran Sea where the axillary seabream stock was identified in overfishing with declining biomass (Baro, 2000). Currently, the only specific management measure applied for the species in the Mediterranean Sea is the minimum landing size (MLS) fixed at 17 cm TL (EC, 2006).

It is well known that the axillary sea bream exhibits protandric hermaphroditism where individuals first mature as males with

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1 Total Length.
2 Length-Weight Relationship.
3 Weight.
4 Average Percent Error.
5 Coefficient of Variation.
6 Essential Fish Habitat.

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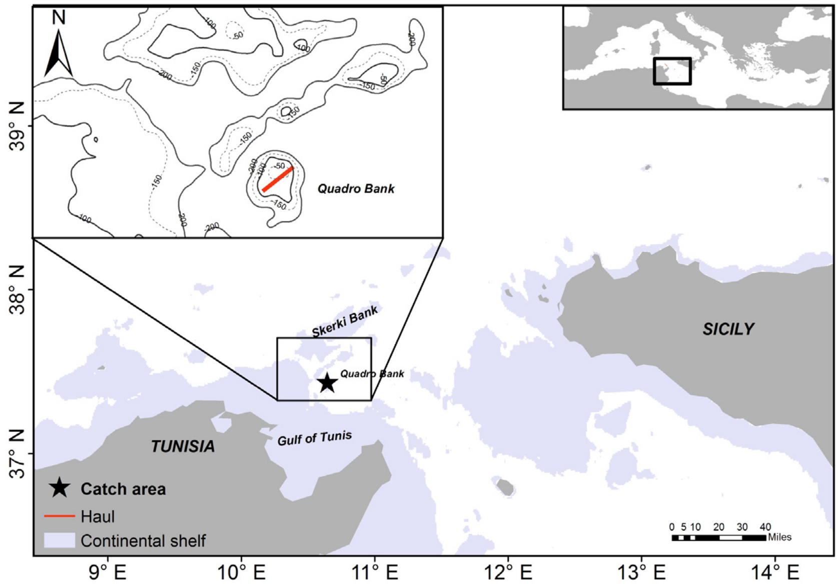

Fig. 1. Map showing the position of the trawl haul (red line) where the spawning aggregation of *P. acarne* was found. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the immature ovarian zone adjoins, then they undergo testicular regression and the ovarian zone becomes functionally female (Le-Trong and Kompowski, 1972; Lamrini, 1986; Reinboth et al., 1986; Pajuelo and Lorenzo, 1994, 2000; Arculeo et al., 2000).

The biology of *P. acarne* has been studied in several areas of the Mediterranean, including the western (Velasco et al., 2010; Bensahla Talet et al., 2013, 2017; Boufersaoui and Harchouche, 2015), the central (Andaloro, 1982; Arculeo et al., 2000; Mokrani et al., 2007) and the eastern basin (Mytilineou, 2000; Soykan et al., 2015).

Available information concerns spawning period, sex-ratio, length at sexual inversion and at first maturity and length weight relationship (LWR), but very few is known about age structure of spawners. Studies on the reproductive biology of fish are important and a basic requirement for effective fishery resources management and conservation (Trippel, 1999). Furthermore, age structure of spawners is more and more recognized as a main factor in success of reproduction since a more age-diverse spawning stock tends to spawn earlier and over a longer period than a stock with few old individuals (Caddy and Seijo, 2002; Longhurst, 2002; Birkeland and Dayton, 2005; Fromentin, 2006; Fiorentino et al., 2008; Brunel, 2010).

The objective of this study is to provide new data on the sex ratio, LWR and age structure of the spawning fraction of *P. acarne* population in the central Mediterranean Sea.

2. Materials and methods

2.1. Study area and sampling

A spawning aggregation of the axillary seabream was caught during a trawl haul carried out by a Sicilian commercial trawler in the international waters of the Quadro Bank (off Tunisian coast) (37°25,92 N–10°37,63 E; 37°28,30 N–10°40,59 E; mean depth 85 m) on October 1st 2016 at sunset (from 18:30 to 19:40, solar time). The catch, composed by 312 adults weighting 38 Kg, was recorded by observers on board in the frame of the monitoring activities of commercial catch (CampBiol) within the European Data Collection Framework (DCF) (Fig. 1).

2.2. Laboratory processing

One third of the catch was randomly sampled and frozen on board. Fish were then processed in laboratory where both total length (TL, to the nearest 0.5 cm) and weight (W, to the nearest 0.1 g) were measured. Sex was evaluated macroscopically by inspection of gonads. Individuals presenting both male and female gonads were considered males if testis were predominant; otherwise females.

2.3. Reproductive aspects

Maturity stages were assessed according to the MEDITS (International Bottom Trawl Survey in the Mediterranean) scale (Anonymous, 2016) based on eight distinct maturity stages: (0) undetermined, (1) immature = virgin, (2a) virgin-developing, (2b) recovering, (2c) maturing, (3) mature/spawner, (4a) spent and (4b) resting.

Sex-ratio (SR) was expressed in the overall sample and by length as:

$$SR = F/(F + M)$$

where F = number of females and M = number of males.

Due to the well know protandric hermaphroditism of the species (Arculeo et al., 2000), the sex-ratio by TL was described by using the logistic function:

$$SR_{(l)} = 1/[1 + exp^{-r(TL-L_{50})}]$$

where L_{50} is the length where 50% of specimens are female, as proxy of the sexual inversion length, and r is a constant (Jennings et al., 2001).

2.4. Length and age methodology of estimates

The LWR was calculated combining sexes and using the classical allometric power function:

$$W = aTL^b$$

where W is the total body weight (g) and *a* and *b* constants (Jennings et al., 2001). Since specimens were frozen in plastic

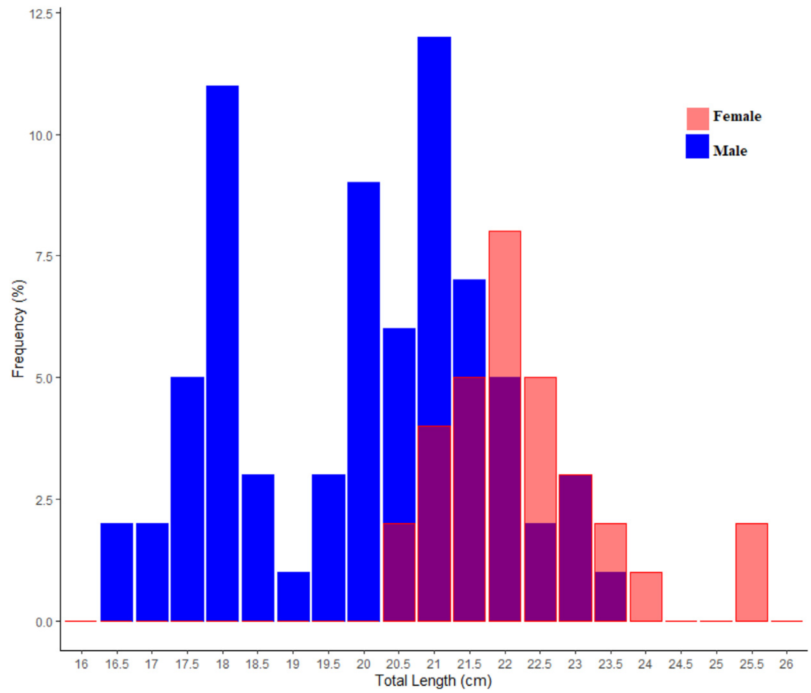

Fig. 2. Length frequency distribution by sex of *P. acarne*. Length frequency distribution of males was bimodal with evident modes at 18 and 21 cm TL, while the females appeared unimodal (22 cm TL).

bags to reduce the moisture loss, the variation in weight between fresh and thawed fish was considered negligible.

Otoliths were collected from each individual for age estimation. In particular, *sagittae* were extracted, cleaned in distilled water and stored dry. Successively, otoliths were read in water under reflecting light by two readers for three times. The incremental growth pattern formed by one opaque and one translucent rings was assumed having annual value (*annulus*). The readers did not have access to information on size and sex while they were counting growth increments. To assess ageing precision between readers, the index of average percent error (APE) (Beamish and Fournier, 1981) and the mean coefficient of variation (CV) (Chang, 1982) were calculated.

The mature status of the fish sampled seems to confirm the knowledge on the species spawning periods in the area (i.e. September–December with a peak in October, Mokrani et al., 2007) as well as supporting the assumption of first of November as the birthday for aging the sampled fish. The first translucent ring was considered the demersal check laid down during bottom settlement after the pelagic life stage (Rizzo et al., 2005; Sieli et al., 2011; Bottari et al., 2016). The ages at length of specimens were finally organized in a classic Age–Length Key (ALK) to give the demographic structure of catch (Morales-Nin and Panfili, 2002).

3. Results

3.1. Length and reproductive analysis

The sample was dominated by males (69.2%) being the sex ratio 0.31 with females (range TL = 20.5–25.5 cm; mean TL = 22.3 ± 1.2 cm) larger than males (range TL = 16.5–23.5 cm; mean TL = 20.0 ± 1.8 cm) ($p < 0.05$). The modal progression analysis (Bhattacharya test) showed a bimodal length frequency distribution for males, with evident modes at 18 and 21 cm TL, while the females appeared unimodal (22 cm TL) (Fig. 2).

Individual weight ranged from 109 to 266 g and 56 to 171 g for females and males respectively ($p < 0.05$).

The estimated length at sexual inversion (LSI_{50}) was 22 cm TL (Fig. 3) (Intercept = −24.72, SE = 5.63; Slope = 1.12, SE = 0.26).

The LWR corresponds to positive allometric growth and the pooled parameters were a = 0.003 and b = 3.5207 (Fig. 4; Table 3).

All the females were mature with ovaries highly vascularized and with ripe and fluent eggs (stage 3, n = 31) or very close to stage 2c (n = 1). A total of 62 (59.6%) males were mature with fluent gonads (stage 3) while 7 (6.7%) were between recovering (stage 2b) and maturing (stage 2c) phases. Only 1 specimen was virgin-developing (stage 2a), with a TL of 16.5 cm and 2 were spent (stage 4a). The mean (±s.d.) size of mature males (stage 2c and 3) was 20.0 ± 1.8 cm TL.

3.2. Age analysis

All the examined specimens were successfully aged. Indices of ageing precision APE and CV were very low (10.38 and 13.12, respectively), showing a good consistency or reproducibility among readings. The age class composition was between II and VI and III and VII for males and females respectively (Fig. 5).

Due to the species' hermaphroditism, the ALK was prepared pooling sex (Table 1).

4. Discussion

According to the literature axillary seabream's reproduction in the Mediterranean Sea occurs between April and December (Table 2). Considering the Strait of Sicily, the spawning season is shorter extending from September to December with a peak in October in the Gulf of Tunis (Mokrani et al., 2007). Our record of a species spawning aggregation in October supports the observation of an autumnal spawning period of the axillary seabream in the Strait of Sicily.

In our sample the overall sex ratio was significantly in favor of males (SR = 0.31), being the lowest value reported in literature (Table 2). No females smaller than 20.5 cm TL and no males

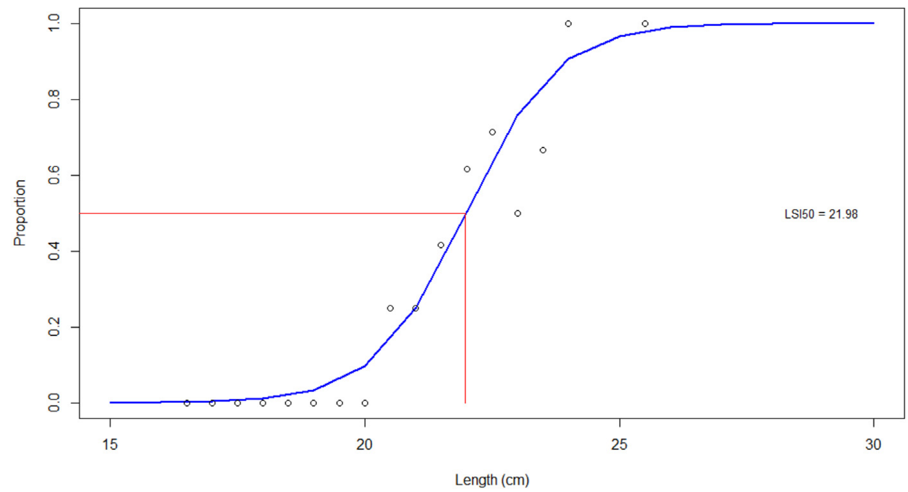

Fig. 3. Logistic curve describing the sex ratio as proportion of F/(F+M) by size of *P. acarne*. An estimated of length sexual inversion (LSI_{50} = 22.0 cm TL) with parameter (Intercept = −24.72, SE = 5.63; Slope = 1.12, SE = 0.26) are given.

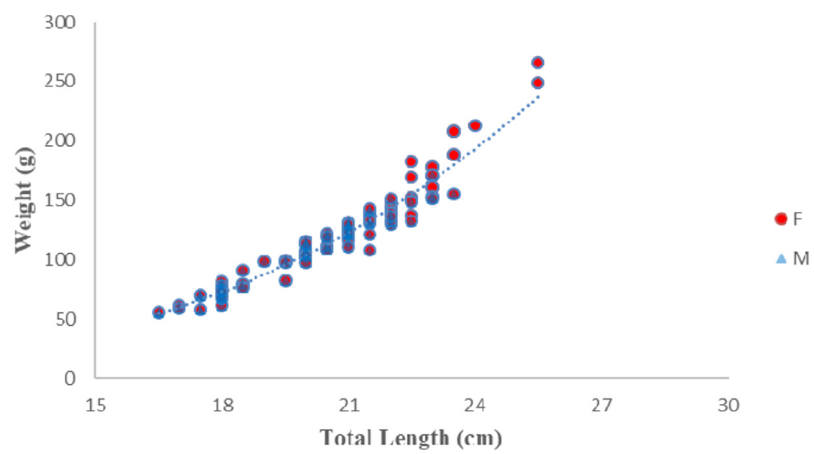

Fig. 4. The length-weight relationship of *P. acarne* (sex pooled). Individual data were reported by sex.

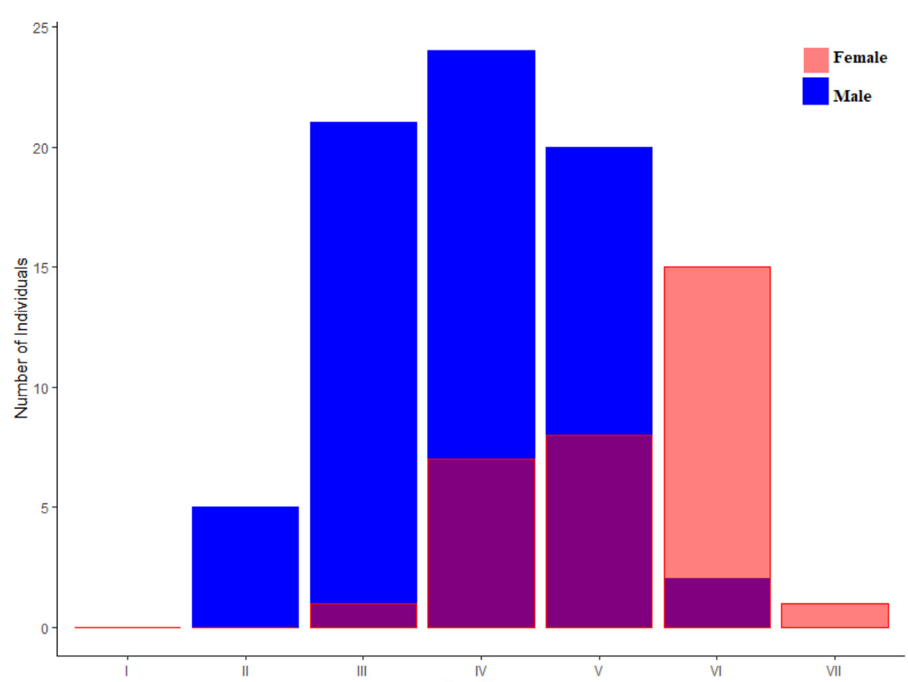

Fig. 5. Age frequency distribution by sex of the *P. acarne* sample.

Table 1
Age–Length Key by pooled sex of the *P. acarne* sample. Years expressed as "Age class".

Total length (cm)	Pooled sex							Total
	Age class							
	I	II	III	IV	V	VI	VII	
16.5		1	1					2
17		1	1					2
17.5		2	3					5
18		1	9	1				11
18.5			3					3
19				1				1
19.5			1	2				3
20			3	5	1			9
20.5			1	6	1			8
21				8	7	1		16
21.5				4	5	3		12
22				3	7	3		13
22.5				1	1	5		7
23					4	2		6
23.5					1	2		3
24						1		1
24.5								0
25								0
25.5					1		1	2
Total	0	5	22	31	28	17	1	104
Mean total length	0	17.3	18.3	20.7	21.9	22.4	25.5	
Standard deviation	0	0.6	1.0	1.0	1.1	0.8	0	

larger than 23.5 cm TL were found confirming the protandric characteristic of this species.

Data on sex inversion, occurring between 20.5 and 23.5 cm TL, generally agreed with literature in the Mediterranean (Boufersaoui and Harchouche, 2015; Dragičević et al., 2015) and in Atlantic (Coelho et al., 2005). Moreover, the length of sexual inversion (LSI_{50}) calculated in this work (22 cm TL) is similar to that estimated by Velasco et al. (2010) in Alboran Sea (21.5 cm TL), but differs from the LSI_{50} value reported by the same authors in the Gulf of Cadiz (23.5 cm TL) (Table 2). It is very interesting to note that, in several studies performed in the Mediterranean Sea, the value of L_{50} for females results lower than the value of the LSI_{50}. We suppose that this phenomenon could be due to the occurrence of primary females in the population, as commonly reported for Sparidae (Buxton and Garratt, 1990).

The minimum landing size regulation set at 17 cm TL, adopted within the European Union Common Fisheries Policy (EC, 2006) for the axillary seabream, seems insufficient to ensure stock renewal and should be increased as already proposed by Bensahla Talet et al. (2017). In particular, considering the medium size of sexual inversion present in literature, it should be very important to increase the MLS at 20 cm in order to reduce the catch of immature individuals.

The LWR of the specimens caught in the Quadro Bank showed strong positive allometry probably as an effect of their maturity condition. Compared to our study, a less strong positive allometry was obtained for both sex around Gulf of Cadiz (Velasco et al., 2010), in the Ionian Sea (Lembo et al., 2012), in the Tyrrhenian Sea (De Ranieri, 2011; Spedicato et al., 2012) and in the Balearic Island (Morey et al., 2003). On the contrary, negative allometric growth was found in the south Adriatic Sea (Carbonara et al., 2012) and in the Aegean Sea (Moutopoulos and Stergiou, 2002) (Table 3). Compared to other studies, the b parameter value of the Quadro Bank individuals was higher, this may be due either to the absence of juveniles in the catch or to the presence of adults with ripe gonads. Both these aspects undoubtedly may influence the fit of the LWR.

The age structure of the spawners ranged between age class II and VII, with a prevalence of age class IV and VI for males and females, respectively. Comparison with von Bertalanffy curves available in literature suggests that our specimens show a similar growth pattern to others, excepting that reported by Soykan et al. (2015) for Izmir Bay (Fig. 6).

Since the age corresponding to the size at first maturity reported by Mokrani et al. (2007) for the Gulf of Tunis (Table 2) should be the age class II, it is worth noting that most of the fish caught on the Quadro Bank on October 2016 were old spawners after their first reproduction.

5. Conclusion

The current consensus is that age structure of spawning stock is a main factor in increasing the success of recruitment in fish (Scott et al., 2006). First-time and young spawners breed for a shorter period, produce fewer egg batches, exhibit lesser fecundity, and produce smaller eggs, with lower fertilization and hatching rates than the older and more fecund females. In the case of protandric hermaphrodite species, such as *P. acarne*, the excessive catch of the older fraction of spawning stock, i.e. the females producing highest quantity of eggs which develop more vital larvae, reduces the spawning stock biomass and might affects the recruitment effectiveness.

Finally, the unusual high catch rate of mature big-sized specimens of axillary seabream, captured during a single haul carried out in 1 h of bottom trawling on October 1st 2016 (n = 312; weight = 37.8 Kg), indicates that the area of Quadro Bank is a spawning area for this species as already verified for several fish species in the Gulf of Tunis (Hattour, 1991; Zarrad et al., 2003).

A very significant phase of the reproductive activity is the spawning aggregation (Sadovy and Domeier, 2005) which is defined as a group of conspecific fish, gathered at a specific site and time for the purposes of spawning, with fish densities significantly higher than densities found during the non-reproductive period (Domeier and Colin, 1997). Given the biological importance of these sites, developing conservation strategies aimed at protecting the functions of those areas is very important to maintaining the sustainability of marine fisheries (Sadovy and Domeier, 2005; Sadovy de Mitcheson and Colin, 2012; Boucek et al., 2017).

Table 2
Biological comparison of data collected by different authors on *P. acarne*. M: males; F: females; P: pooled sex; NA: not available.

Region	Sex ratio F/(F+M)	L min–L max (cm)	Size of sexual inversion (LSI_{50}) (cm)	Size of first maturity (L_{50}) (cm)	Spawning period	Source
Tyrrhenian and Ionian Sea	NA	8–28 (P)	NA	16.5 (P)	July→September	Andaloro (1982)
Strait of Messina	0.32	18–22 (P)	NA	NA	August	Arculeo et al. (2000)
Algarve	0.66	12.4–36.5 (P)	20–24	18.1 (M) 17.6 (F)	May→September May→November	Coelho et al. (2005)
Gulf of Cadiz	0.49	11.3–30.9 (P)	23.5	18.04 (M) 21.7 (F)	April→June April→June	Velasco et al. (2010)
Alboran Sea	0.50	10.7–29.4 (P)	21.5	17.7 (M) 20.1 (F)	May→October May→October	
Algerian Sea	NA	11.3–24.3 (M) 10.8–28.1 (F)	19–24	16.8 (M) 16.5 (F)	NA	Boufersaoui and Harchouche (2015)
Gulf of Tunis	0.38	11.4–25.5 (P)	NA	15.68 (M) 16.27 (F)	September→December	Mokrani et al. (2007)
Adriatic Sea	NA	9.3–29.5 (P)	16.1–25.5	16.1 (M) 17.7 (F)	September→October	Dragičević et al. (2015)
Izmir Bay	0.78	8.5–20.2 (P)	NA	13.91 (M) 14.45 (F)	June→September	Soykan et al. (2015)
Alboran Sea	NA	NA	20.5–20.9	19 (P)	May→October	Baro (2000)
Algerian Sea	0.56	11.9–26.3 (P)	NA	15.99 (M) 12.75 (F)	May→December	Bensahla Talet et al. (2013)
Quadro Bank	0.31	16.5–23.5 (M) 20.5–25.5 (F)	22	NA	October	Present study

Table 3
Parameters of the LWR of *P. acarne* in different areas. NA: not available.

Area	Sex	N	a	b	r^2	Reference
Quadro Bank	Pooled	312	0.003	3.5207	0.95	Present study
Gulf of Cadiz	Pooled	461	0.0048	3.3207	0.98	Velasco et al. (2010)
Alboran Sea	Pooled	406	0.0093	3.1132	0.94	
Izmir Bay	Pooled	842	0.009	3.138	0.97	Soykan et al. (2015)
Mersin Bay	Pooled	901	0.0075	3.146	0.94	Cicek et al. (2006)
Algarve	Pooled	370	0.012	3.048	0.98	Coelho et al. (2005)
Baie d'Oran	Pooled	844	0.0089	3.1006	0.96	Bensahla Talet et al. (2013)
Ligurian and North Tyrrhenian Sea	Pooled	NA	0.0062	3.26	NA	De Ranieri (2011)
South Tyrrhenian Sea	Pooled	NA	0.0068	3.22	NA	Spedicato et al. (2012)
South Adriatic Sea	Pooled	NA	0.0288	2.71	NA	Carbonara et al. (2012)
Ionian Sea	Pooled	NA	0.0057	3.28	NA	Lembo et al. (2012)
Aegean Sea	Pooled	NA	0.0150	2.93	0.97	Moutopoulos and Stergiou (2002)
Balearic Island and Iberian Coast	Pooled	140	0.0660	3.21	0.995	Morey et al. (2003)
Aegean Sea	Pooled	334	0.0104	3.06	0.933	Ilkyaz et al. (2008)
South Tyrrhenian Sea and North Ionian Sea	Pooled	NA	0.0096	3.02	NA	Andaloro (1982)

Although there is growing interest in studies focused on the spawning aggregation of fish (e.g. Boucek et al., 2017; Roff et al., 2017; Stump et al., 2017) worldwide, in the Mediterranean Sea the ongoing knowledge is scarce (Aronov and Goren, 2008; Ganias, 2008). Fiorentino et al. (2001) described the age structure of a spawning aggregation of brown meagre *Sciaena umbra* (Linnaeus, 1758) caught in the Strait of Sicily (Maltese waters) during a single fishing operation. Also if limited in space and time, our record suggests the importance of the Quadro Bank as Essential Fish Habitat for completing the life cycle of *P. acarne*. Accumulating this kind of information is essential to develop management measures aimed to preserve the replacement capability of exploited stocks and pursue sustainable fisheries strategies.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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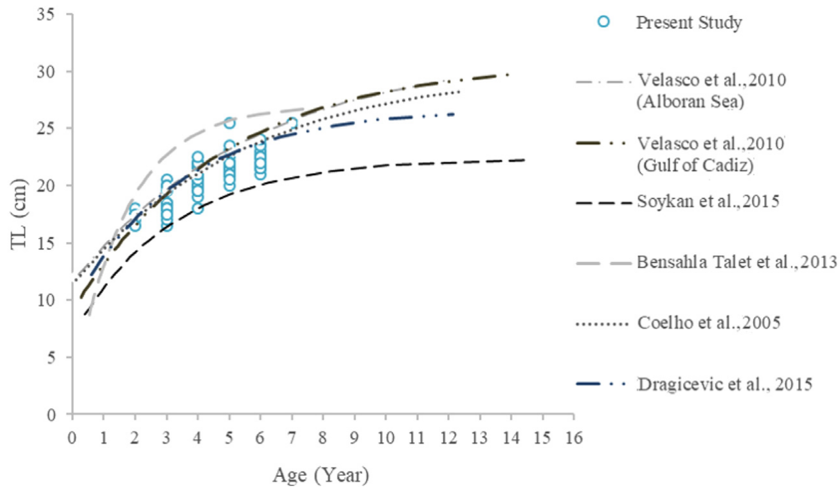

Fig. 6. Length-at-age of *P. acarne* recorded off the Quadro Bank plotted with published von Bertalanffy growth.

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