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New insights on the biological parameters of the exploited cuttlefish *Sepia officinalis* L. (Mollusca: Cephalopoda) in the northern Adriatic Sea in relation to the main fishing gears employed

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Abstract

The cuttlefish (*Sepia officinalis* Linnaeus 1758) represents one of the most important coastal fishery resources of the Mediterranean Sea. For Italy, almost half (45%) of cuttlefish landings (2,328 t) originate from coastal regions of the northern Adriatic Sea: Veneto, Marche, Emilia Romagna and Friuli Venezia Giulia. In terms of economic value this species represents about 8% (~ € 16.5 million) of the production from this basin. From May 2004 to October 2005, cuttlefish were purchased from commercial landings of the Grado fishery fleet. At least 30 specimens were randomly taken each month from each fishing method employed for this species: bottom trawl (cod end mesh size 40 mm), *rapido* trawl, trammel net (mesh size of inner panel 30 mm) and cuttlefish specific trap. The main biological aspects, such as size, sex ratio, reproductive stage and diet in relation to both the season and type of fishing gear were analyzed. 1,495 specimens, ranging from 3.5 to 18.0 cm mantle length, were analyzed. In relation to the observed size and reproductive stage of individuals caught, trammel nets and cuttlefish traps both appeared to target sexually mature individuals, whilst trawling gear were not selective for either recruits or spawners. In total, 34 prey taxa were found in the stomachs of *S. officinalis*: crabs and bony fish species were the most important prey, although the latter were found mostly in the largest specimens. Finally the fullness index revealed that cuttlefish caught by trawling were more suitable for diet analysis than those caught by static gear. In this way the contribution of this paper was to give new insights on the biological parameters of this species in relation to the main fishing gears employed in the northern Adriatic Sea.

Keywords: *Sepia officinalis*; sexual maturity; diet; fishing gear; northern Adriatic Sea.

Introduction

The common cuttlefish, *Sepia officinalis* Linnaeus 1758, is one of the most studied cephalopods worldwide. It is a demersal and neritic species occurring from the coastline to about 200 m depth, predominantly on sandy and muddy bottoms (Guerra & Castro, 1988). *Sepia officinalis* is found in eastern Atlantic shelf waters from southern Norway and northern England to North West Africa at Cap Blanc on the southern border of Mauritania (Boletzky, 1983; Khromov *et al.,* 1998). It is also recorded throughout the Mediterranean basin, but its suspected absence in the Black Sea remains to be confirmed (Salman *et al.,* 2002). The common cuttlefish inhabits the entire coastal part of the Adriatic Sea (Gamulin Brida & Ilijanić, 1972). It migrates seasonally: in winter it resides mostly in the circalittoral zone where it matures sexually and then in spring it migrates to the shallower infralittoral belt in order to spawn (Mandić, 1984). In the central and northern Adriatic, the species occurs predominantly on sandy and muddy bottoms up to 100-150 m deep (Manfrin Piccinetti & Rizzoli, 1984; Soro & Manfrin Piccinetti, 1989; Županović & Jardas, 1989; Casali *et al.,* 1998), being more abundant in coastal waters on seagrass meadows and sandy bottoms (Ezzeddine-Najai, 1997). Like the majority of cephalopod species, the biological and ecological characteristics of *S. officinalis*, and also its stock assessment, have been insufficiently investigated in the Adriatic Sea. Nevertheless, on the basis of comparative microsatellite variation analysis, Garoia *et al.* (2004) suggested the occurrence of a single genetically homogeneous population within the Adriatic stocks of this species. *Sepia officinalis* can grow to a maximum of 35 cm (mantle length) and live for approximately two years, although some male individuals may attain a greater age (Guerra, 2006). The spawning period of this species extends throughout the year in the western Mediterranean, with peaks in spring and summer (Mangold-Wirz, 1963). In the northern and central Adriatic Sea it reproduces in April and May, but females with mature eggs can even be found in June and July (Manfrin Piccinetti & Giovanardi, 1984). The diet of *S. officinalis* includes crustaceans, bony fishes, molluscs, polychaetes and nemertean worms (Nixon, 1987; Castro & Guerra, 1990; Pinczon du Sel *et al*., 2000).

Together with the common octopus (*Octopus vulgaris*), *S. officinalis* undoubtedly represents one of the most important coastal fishery resources of the Mediterranean Sea (Voss, 1973; Belcari & Sartor, 1993; Sanchez *et al*., 1998; Jereb & Roper, 2005), where it is an established resource that is exploited at both industrial and small-scale levels, including recreational angling (Belcari *et al*., 2002). Historically, captures and utilization of the cuttlefish have been very important in this area and discards are still virtually absent in Mediterranean fisheries (Sartor *et al*., 1998). In some other areas, like the English Channel, this resource, previously discarded, has come to be appreciated in more recent decades and a rapid increase in landings has been observed (Dunn, 1999). In terms of yields, the cuttlefish is currently the most important cephalopod caught in the north-east Atlantic, and the main fishing ground for this resource is the English Channel, which represents the northern limit for the reproduction of this species (Royer *et al*., 2006). Furthermore, in Galicia, the base of Europe's largest fishing fleet (Rocha *et al*., 2004), the small-scale fishery of *S. officinalis* represents a very important socio-economic activity, with cephalopods being among the most important resources exploited in this area (Rocha *et al*., 2006). In the Adriatic Sea, cuttlefish are caught mainly by bottom and beam (*rapido*) trawl nets, but trammel nets, fyke nets and specific pots are used, as well (Fabi & Sartor, 2001). In 2012, the Italian production of cuttlefish amounted to 5,149 tons, of which 2,681 tons were from trawl and 2,406 tons from artisanal fishery (trammel nets and cuttlefish pots). Moreover, 45% of this production (2,328 t) originated from the coastal regions of the northern Adriatic Sea: Veneto, Marche, Emilia Romagna and Friuli Venezia Giulia (IREPA, 2014). In terms of the main annual economic value, *S. officinalis* represented 8% (~ € 16.5 million) of the production in this basin (2012 data; IREPA, 2014).

The aim of this work was to analyze the main biological aspects of *S. officinalis*, such as size, sex ratio, reproductive stage and diet in relation to both the season and the type of fishing gear employed in the northern Adriatic Sea. The selected parameters are fundamental for the preparation of an effective monitoring program, aimed at sustainable exploitation of this commercially important species.

Material and Methods

Study area

The northern Adriatic Sea is considered to be one of the most profitable for the cuttlefish fishery, particularly in the northernmost sector, the Gulf of Trieste (Coglievina, 1934; Piccinetti *et al.,* 2012). Cuttlefish samples were caught by the fishery fleet of Grado, whereas data on commercial landings were recorded by the adjacent fleet of Marano Lagunare (Fig. 1). Both fleets operate on the same fishing ground, off the Lagoon of Marano and Grado and together represent almost 80% of the fisheries capacity in the Gulf of Trieste, without considering the contribution of Slovenian ports such as Koper, Izola and Piran. The total number of vessels operating in Grado and Marano Lagunare were 20 bottom trawls (mean length 15.3 m), 12 *rapido* trawls (16.5 m), 30 vessels using trammel nets (10 m) and about 100 vessels with cuttlefish traps (6.6 m). The crew members are normally three for trawlers, two for trammel nets and one for traps. The use of bottom trawls for cuttlefish in the study area was permitted at a distance of 1.5 NM from 1th April to 15th June (Froglia *et al*., 2000), but due to Council Regulation (EC) No. 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, since 1th June 2010, the use is only authorized at a distance of 3 NM. Static gears for cuttlefish are normally set inshore.

Sampling and data analysis

From May 2004 to October 2005, cuttlefish were purchased from commercial landings of the Grado fishing fleet. At least 30 specimens were randomly taken each month from each fishing method employed for this species: bottom trawl (cod end mesh size 40 mm) (hereafter BT), *rapido* trawl (RT), trammel net (mesh size of inner panel 30 mm) (TN), and cuttlefish specific traps (FT), normally not baited in the study area.

Each cuttlefish was measured to the nearest millimetre (dorsal mantle length, ML), sexed and the stage of sexual maturity determined according to the scale adopted by Scarcella *et al.* (2002), on the basis of Mangold-Wirz (1963) and Lipinski (1979) indications: I immature, II maturing, III mature and IV fully mature. For seasonal considerations, months were grouped as follows: spring – April to June, summer – July to September, autumn – October to December, winter, January to March.

The digestive tract was removed and the fullness index (FUI) of the stomach was recorded using a subjective scale from 0 to 4: 0 – empty, 1 – 25% of its volume, 2 – from 25% to 50% of its volume, 3 – from 50% to 75% of its volume, 4 – full (Castro & Guerra, 1990). Each stomach was preserved in 70% ethanol and contents were analyzed at a later stage. All prey were identified to the lowest possible taxon level, according to the following criteria: crustaceans were identified from eyes, mandibles or appendages (Falciai & Minervini, 1992); bony fishes were detected from otoliths; microgastropods, ostracods, copepods and bivalve molluscs were not taken into account; remains of algae and marine phanerogams were not considered as prey. Due to the loss of samples during the relocation of the Department, most of the otoliths were not analyzed and Osteichthyes species remained

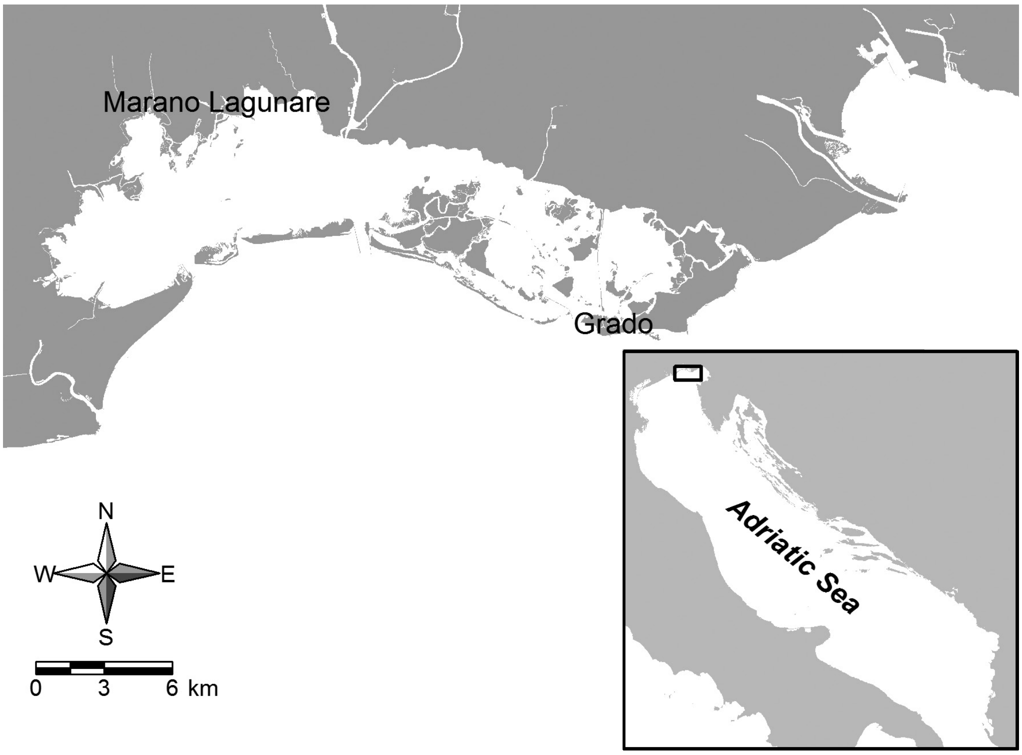

Fig. 1: Map of the study area in the northern Adriatic Sea. Cuttlefish (*S. officinalis*) samples were caught by the fishery fleet of Grado, whereas data on commercial landings were recorded by the adjacent fleet of Marano Lagunare.

undetermined. Whole organisms were never encountered in the stomachs examined, since cuttlefish break up the prey during ingestion (Guerra *et al.,* 1988). The diet was quantified according to Mendes Alves *et al*. (2006), where the index of relative importance (IRI%) was used (Hyslop, 1980), taking into account the number of prey items and their frequency of occurrence (Laroche, 1982; Govoni *et al*., 1983; Borme *et al*., 2013). IRI% was calculated for all specimens and for groups on the basis of sex, season, mantle length (ML < or > 6.5 cm, Castro & Guerra, 1990) and fishing gear; a paired t-test was used to analyze the prey taxa between these groups (Zar, 2010).

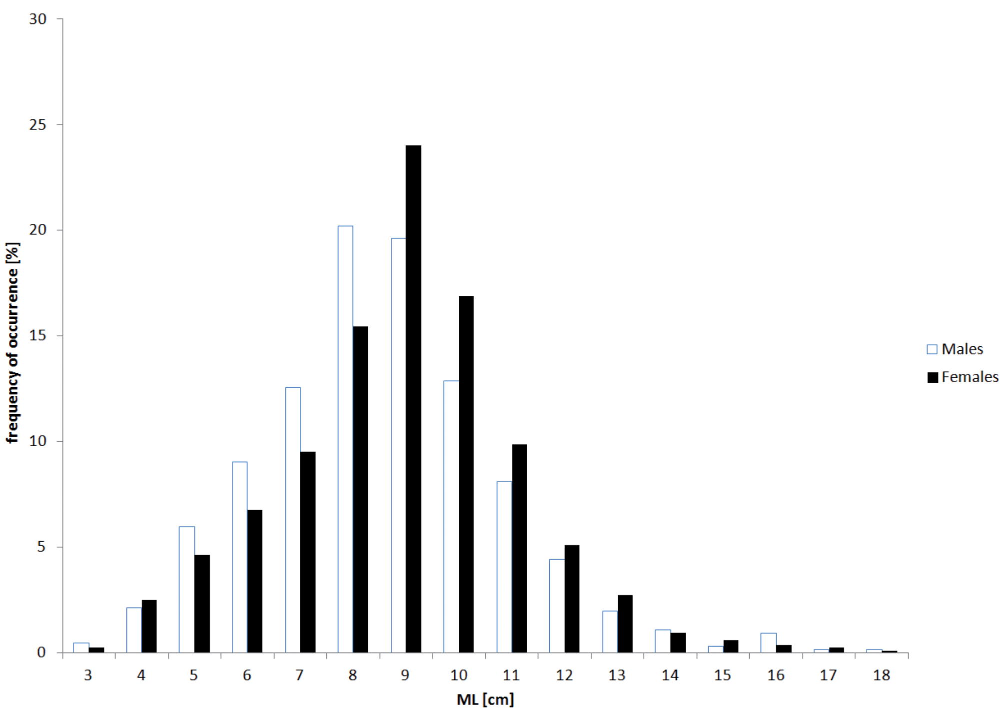

Fig. 2: Length frequency of male and female cuttlefish (*S. officinalis*).

Moreover, in order to compare the cuttlefish landings with different fishing gear, data on commercial landings were collected monthly at the fish market of Marano Lagunare. In this work we were able to collect complete monthly data for 2005, 2006 and from 2009 to 2012.

Results

Size and reproduction

In this study 1,495 specimens were analyzed, ranging from 3.5 to 18.0 cm ML (average ML 9.3 ± 2.2 cm): 654 males (average ML 9.1 ± 2.3 cm) and 841 females (average ML 9.4 ± 2.2 cm). The ML of females was significantly longer than that of males (t-test, $t = 2.669$; $p \leq 0.01$) and the size distribution of both sexes was unimodal (Fig. 2). The ML range for each fishing method is shown in Table 1, and the t-test revealed that cuttlefish caught by TN and FT were significantly longer than those caught by BT and RT. Moreover, the size distribution was unimodal for all fishing methods (Fig. 3). The comparison of ML distribution between trawls (RT+BT) and static gear (TN+FT) for each season is shown in Fig. 4. During spring the mean ML of specimens caught by various types of static gear was slightly higher than the mean ML of specimens caught by trawling. During the summer and autumn there was an increasing difference between the mean ML of the two types of gear, whereas in the winter this species was caught by trawling (Table 2).

Females prevailed over males, with a significant deviation from the theoretical 1:1 sex ratio, although males were more abundant in the fish traps (Table 3). Sex maturity in relation to size (Fig. 5) shows that males were more precocious than females: fully mature males of 6 cm ML were observed, while the first fully mature female measured 7 cm ML. Maturation in both sexes showed an evident annual cycle (Fig. 6): the fully mature females (stage IV) disappeared from commercial landings in September, when immature individuals dominated (stage I),

Table 1. Mantle length (in cm) and t-test (*significant values, p≤0.05) in relation to fishing method: BT - bottom trawl, RT - rapid trawl, TN - trammel net, FT - fish trap.

	n. ind.	min	max	mean±s.d.	t-test (RT)	t-test (TN)	t-test (FT)
BT	407	3.5	17.5	8.6±2.3	1.03	***11.094**	***10.53**
RT	490	4	18	8.5±2.1		***13.489**	***12.606**
TN	344	7.7	18	10.3±1.8			0.146
FT	254	6.9	17	10.3±1.8			

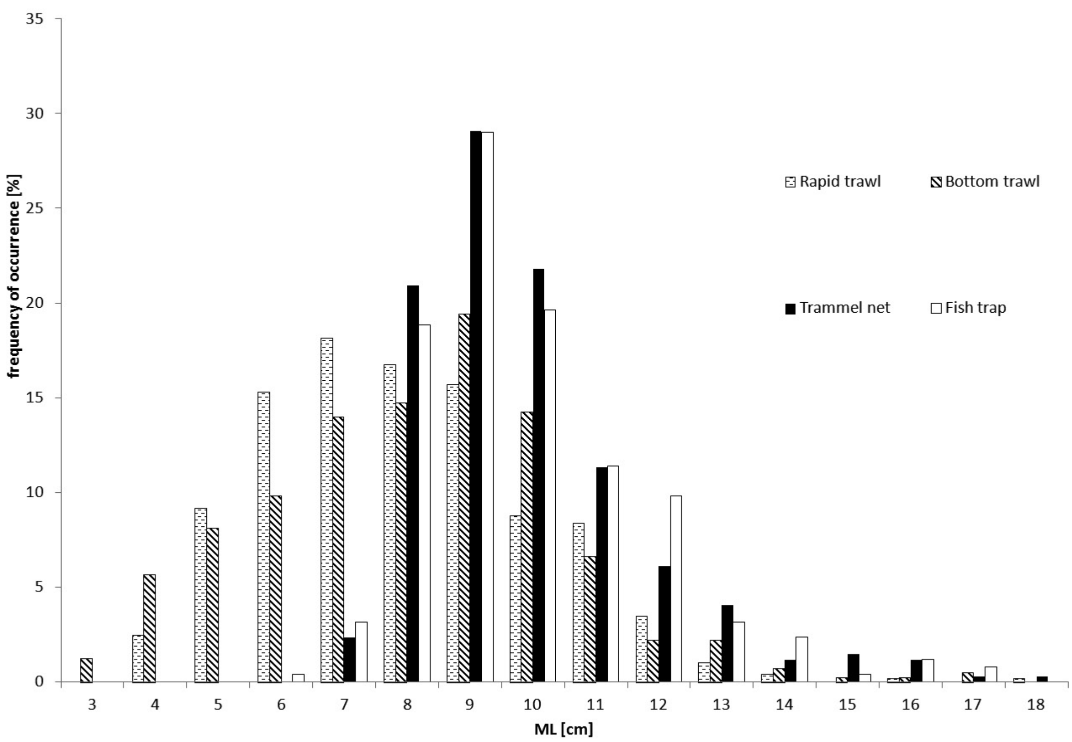

Fig. 3: Length frequency of S. *officinalis* for four fishing methods: bottom trawl, rapido trawl, trammel net and cuttlefish specific trap.

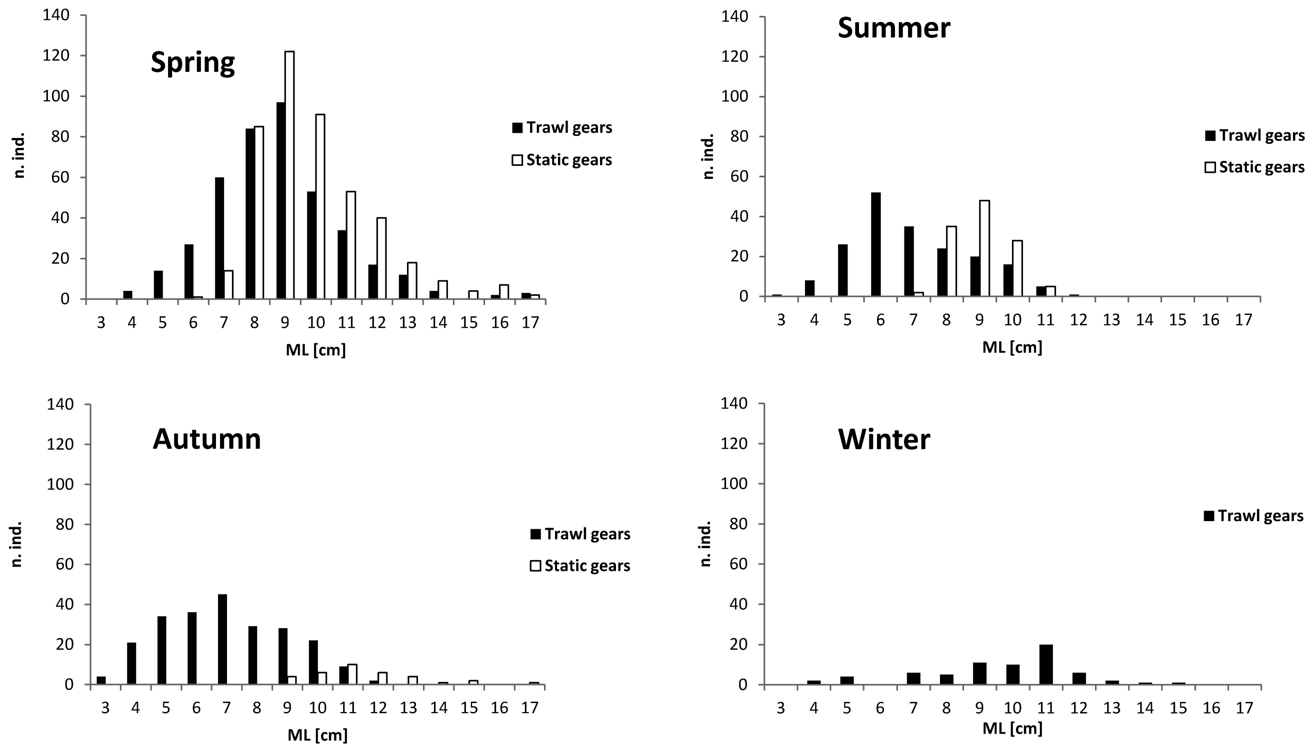

Fig. 4: Length frequency of *S. officinalis* caught by trawls (bottom and rapido) and static gears (trammel net and cuttlefish trap) in relation to season.

followed by an increasing proportion of stages II and III during autumn months. Fully mature females appeared from April, when 53% of specimens were ready for reproduction, until August (Fig. 6). Male maturation took place in September, when about 70% of specimens were at stage II and in December when about 80% of males were fully mature (stage IV) (Fig. 6).

Table 2. Comparison of mantel length values (in cm) between trawls and static gears in relation to season (t-test; *significant values, p≤0.05).

	ML	spring	summer	autumn	winter
trawls	*mean*	9.3	7.5	7.6	10.2
	SD	2.1	1.7	2	2.3
	n	411	188	230	68
static gears	*mean*	10.4	9.5	12	
	SD	1.9	0.8	1.9	
	n	446	118	34	
	t	***8.315**	***13.519**	***12.652**	

Diet

About 54% of all specimens showed empty stomachs (FUI 0), whereas only 7% had completely full stomachs (FUI 4). The FUI was conditioned by the fishing method: empty stomachs prevailed in static gears. In addition, the values of the FUI were similar between BT and RT, as well as between TN and FT (Fig. 7).

In total, 34 prey taxa were found in the stomachs of *S. officinalis* (Table 4). Stomatopods, *Liocarcinus* sp. and Osteichthyes represented approximately 77% of IRI. The diet of males and females did not show any significant differences and no seasonal variations were revealed, although IRI% for Osteichthyes was notably higher during the spring, whereas for *Liocarcinus* sp. this index increased in the summer and autumn. On the contrary, significant differences were revealed among the size classes ML < 6.5 cm and ML > 6.5 cm: smaller specimens (ML < 6.5 cm) ingested 15 taxa, whereas the larger ingested 32 taxa. Moreover, IRI% for Osteichthyes increased from 7% for ML < 6.5 cm to 36% for ML > 6.5

Table 3. Sex ratio of cuttlefish caught, with a significant departure from the theoretical 1:1 sex ratio (Chi-square test).

Fishing method	n. males	n. females	total	sex ratio (m/f)	χ2	*p*
rapid trawl	198	292	490	0.4	18.03	<0.001
bottom trawl	160	247	407	0.39	18.6	<0.001
trammel net	144	200	344	0.42	9.12	<0.005
fish trap	152	102	254	0.6	9.84	<0.005

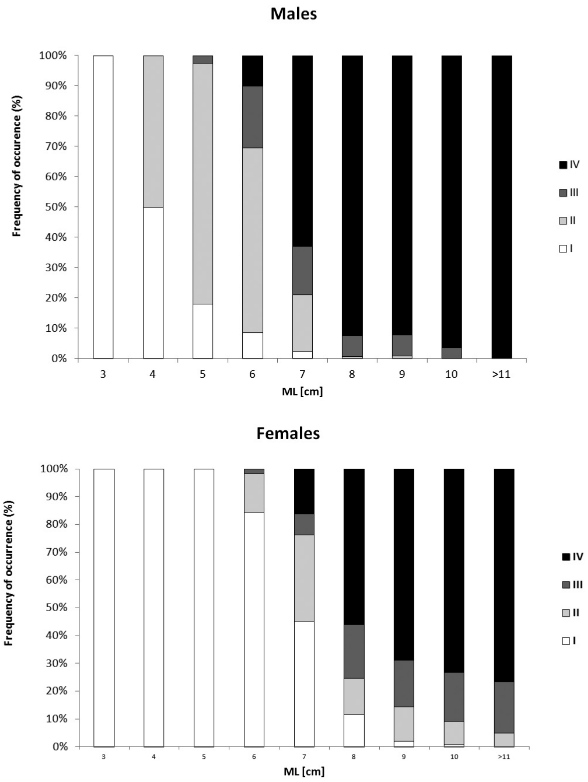

Fig. 5: Sex maturity of male and female cuttlefish in relation to size: I - immature, II - maturing, III - mature, IV - fully mature.

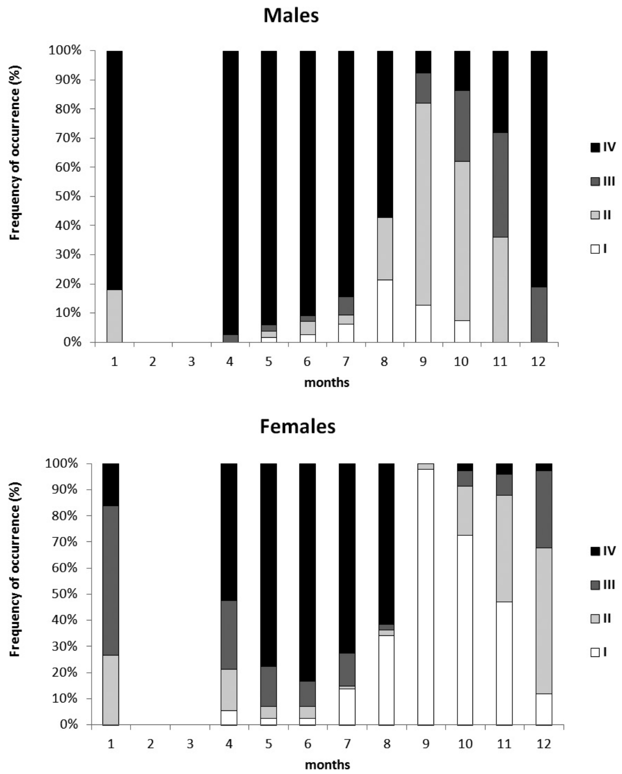

Fig. 6: Sex maturity for male and female cuttlefish in relation to months of the year: I - immature, II - maturing, III - mature, IV - fully mature.

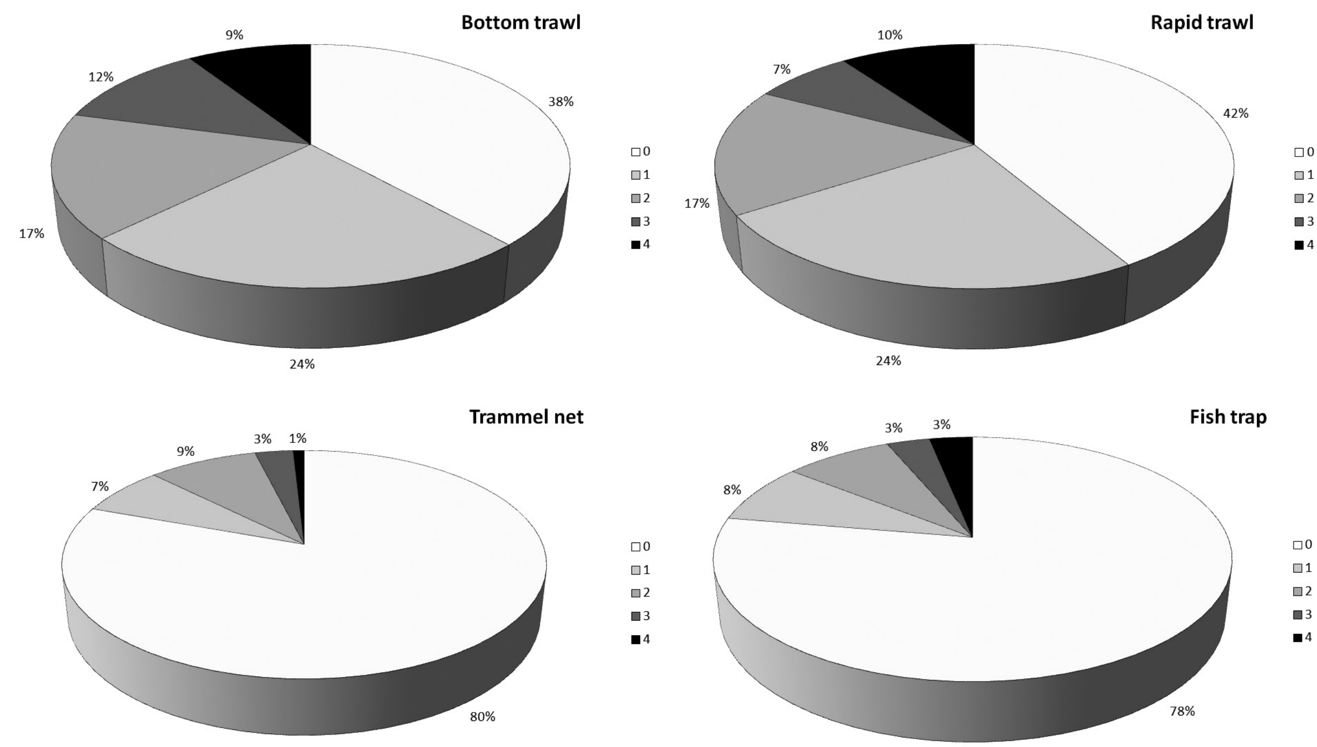

Fig. 7: Fullness index of cuttlefish stomachs in relation to fishing methods: 0 - empty, 1 - 25%, 2 - 25% to 50%, 3 - 50% to 75%, 4 - full.

Table 4. Prey taxa, IRI% values and paired t-test in relation to sex, season, size and fishing method.

Prey taxa (IRI%)	**total**	**males**	**females**	**spring**	**summer**	**autumn**	**ML<6.5 cm**	**ML>6.5 cm**	**trawls**	**static gears**
Polychaeta indet.	0.027	0.014	0.034	0.013	0.022	0.129	0.070	0.030	0.050	
Bivalvia indet.	0.007	0.054				0.129		0.013	0.012	
Cephalopoda indet.	0.492	1.358	0.187	2.197	0.196	0.032		0.964	0.378	3.324
Stomatopoda indet.	**19.484**	**21.730**	**17.162**	**22.933**	**23.705**	**30.930**	**15.712**	**28.225**	**29.393**	**9.234**
Decapoda indet.	2.522	7.823	0.803	6.877	0.435	2.060	2.933	3.415	2.718	7.479
Natantia indet.	0.015		0.034	0.052		0.032		0.030	0.028	
Sicyonia carinata	0.003		0.008		0.044			0.007	0.006	
Athanas nitescens	0.002		0.004	0.013				0.003	0.003	
Processa macrophthalma	0.082	0.204	0.034	0.013		0.772		0.160	0.150	
Processa sp.	0.572	0.489	0.573	2.652	0.087			1.120	1.050	
Crangonidae indet.	0.020	0.081	0.004	0.156				0.040	0.037	
Philocheras sp.	0.002		0.004		0.022		0.070		0.003	
Philocheras monacanthus	0.002		0.004	0.013				0.003	0.003	
Upogebia tipica	0.007	0.054		0.052				0.013	0.012	
Brachyura indet.	3.819	4.387	3.303	1.872	13.409	3.540	16.620	3.401	6.429	0.369
Paguridea indet.	0.002	0.014		0.013				0.003	0.003	
Galatheidae indet.	4.425	9.167	2.389	5.187	13.605	1.159	15.712	4.318	8.122	
Galathea sp.	0.334	0.489	0.245	0.208	2.177		0.628	0.403	0.612	
Galathea intermedia	0.265	0.122	0.344	0.013	2.873		3.911	0.083	0.487	
Pisidia sp.	0.221	0.543	0.096		1.175	0.515	0.628	0.233	0.406	
Pisidia longimana	0.002		0.004					0.003	0.003	
Leucosiidae indet.	0.170	0.217	0.138	0.013	1.393	0.032	0.279	0.213	0.312	
Ebalia sp.	0.002		0.004					0.003	0.003	
Brachyrhyncha indet.	0.034	0.054	0.023	0.260				0.067	0.062	
***Liocarcinus* sp.**	**40.434**	**18.063**	**52.923**	**1.430**	**30.475**	**32.829**	**29.330**	**14.679**	**19.418**	**5.910**
Pilumnus sp.	0.002		0.004		0.022			0.003	0.003	
Portunidae indet.	4.600	5.704	3.792	9.126	1.067	11.007	6.983	5.879	4.508	18.098
Oxyrhyncha indet.	0.002	0.014			0.022		0.070		0.003	
Majidae indet.	0.007		0.015			0.129	0.070	0.003	0.012	
Isopoda indet.	0.002	0.014			0.022			0.003	0.003	
Synisoma sp.	0.003		0.008	0.026				0.007		0.185
Osteichthyes indet.	**22.290**	**29.336**	**17.663**	**46.750**	**9.142**	**16.286**	**6.983**	**36.375**	**25.566**	**53.093**
Syngnathus sp.	0.043	0.014	0.061	0.013	0.087	0.129		0.083		2.308
Gobiidae indet.	0.109	0.054	0.138	0.117	0.022	0.290		0.213	0.200	
n. taxa	34	24	29	24	21	17	15	32	32	9
paired t-test		**males *vs* females**	***-0.307***	**spring *vs* summer**	***0.382***	***n.s.***	**<6.5 *vs* >6.5**	***-2.979***	**trawl *vs* static gear**	***5.884***
			n.s.	**summer *vs* autumn**	***0.916***	***n.s.***		***p<0.001***		***p<0.001***
				autumn *vs* spring	***-0.274***	***n.s.***				

Table 5. Cuttlefish production at the Marano Lagunare fish market in relation to fishing method, tons/year and season percentage.

year	bottom trawl	rapid trawl	trammel net	fish trap	total production
2005	30.03	21.15	41.98	16.44	**109.61**
2006	42.48	31.06	41.47	52.89	**167.9**
2009	32.9	24.45	46.98	23.68	**128.01**
2010	18.02	12.08	36.12	6.55	**72.77**
2011	5.22	7.49	19.68	5.14	**37.53**
2012	11.7	8.16	22.9	5.67	**48.43**
winter (%)	6	20.5	1.9	0	
spring (%)	53.5	29.9	91.6	95.8	
summer (%)	10.2	13.2	5.9	4.2	
autumn (%)	30.3	36.4	0.6	0	

cm. Finally, comparison between trawls and static gear showed clear differences in terms of prey taxa ingested. Additionally the prey category Osteichthyes was present in 53% of the individuals with food in the stomachs caught by static gears.

Fisheries production

The yearly production of cuttlefish for the Marano Lagunare fishing fleet ranged from 37.53 t in 2011 to 167.9 t in 2006: a sharp decrease is evident since 2010, despite the lack of complete monthly datasets for 2007 and 2008. About 37% of the landings derived from TN, followed by BT (Table 5). Spring was the most productive season for static gears, whereas trawl systems caught this resource in autumn also, when the production of RT prevailed (Table 5).

Discussion and Conclusions

Cuttlefish landings showed a mean ML (9.3 ± 2.2 cm), which is somewhat lower than the value (11.7 ± 2.9 cm) recorded by Jardas *et al*. (2001) along the eastern Adriatic coast (Croatia), where total cuttlefish landings caught by trammel bottom sets ranged from 6.5 to 25.5 cm. Therefore, specimens caught by static gears (TN and FT) were more comparable to the dataset of Jardas *et al*. (2001). It is clear that trawling (bottom trawl and *rapido*) was responsible for the smallest specimens caught in the study area, which is in accordance with the study of Belcari *et al*. (2002) in the port of Livorno (Ligurian Sea), where the mode of ML for trawling was 8 cm.

The use of different gear was characterized by a clear seasonality. This was previously pointed out by Belcari *et al*. (2002), since trammel nets and traps mostly catch cuttlefish in spring-summer, whereas trawling gear prevail during autumn-winter. After the temporary suspension (30 to 45 days) of bottom and mid-water trawling nets during summer, trawl gear were responsible for the capture of recruits (identified as specimens with a mantle length below 6 cm) during the summer-autumn period (Piccinetti *et al.,* 2012).

In this study, females prevailed over males, as recorded by Guerra & Castro (1988) in the Ria de Vigo (Spain). On the contrary, sex ratio was in favour of males along the eastern Adriatic coast (Jardas *et al*., 2001). In any event, Pinczon du Sel & Daguzan (1997) suggested that the sex ratio can be related to the fishing method used. In fact, Guerra & Castro (1988) recorded a well-balanced sex ratio in set net fishery, whereas trawling caught more females and conversely males prevailed in the traps, as in this study. The prevalence of males in the traps during spring could be related to the behaviour of *S. officinalis*. In fact Scarcella *et al.* (2002), who analyzed the catching mechanism of traps, pointed out that males were attracted by the presence of females inside, whereas the entry of females appeared to follow a casual pattern; in addition, most of the specimens caught were fully mature for reproduction. However, the sex ratio can also be related to the season and the size of specimens (Guerra & Castro, 1988).

The general maturation pattern in the northern Adriatic Sea coincided with that observed by Mangold-Wirz (1963) in the western Mediterranean and Guerra & Castro (1988) in the Ria de Vigo. These authors also noted that the species may attain sexual maturity at different sizes, the males being more precocious than the females. The minimum size of fully mature males in the mentioned studies corresponds well with our observations (6 cm ML), whereas in females we found fully mature specimens with 7 cm ML. In the Adriatic Sea, Manfrin Piccinetti & Giovanardi (1984) reported an ML at first sexual maturity of about 10 cm for both sexes. Nevertheless, the common cuttlefish can exhibit variations in its life cycle along its geographic range. Around the Iberian Peninsula and in the Mediterranean Sea, the size of spawning females ranges from 9 to 32 cm ML, suggesting the presence of two-year classes of breeders in the population (Guerra, 2006). Since Manfrin Piccinetti & Giovanardi (1984) estimated the population at first sexual maturity in the Adriatic Sea to be 1 year of age, we can only speculate that the average age of specimens analyzed during our study belonged to the first year class, being unimodal in size distribution. More consistent sampling efforts focused during the reproductive period could confirm the presence or absence of a second cohort in this area. In addition, age studies through quantification of the statolith increment (Bettencourt & Guerra, 2001; Domingues *et al*., 2006) should be performed.

Again, according to Manfrin Piccinetti & Giovanardi (1984), in the northern and central Adriatic Sea, the reproduction of *S. officinalis* occurs in spring-summer, with a peak in April and May. Therefore, the employment of static gear is focused on the reproductive period of the species (Froglia, 1976), when cuttlefish migrate inshore towards shallower waters with muddy and sandy bottoms covered with seaweed and phanerogams. Egg masses are attached in clusters to various plants, sessile animals such as tube worms, or dead structures such as drowned trees, cables or nets (Guerra, 2006). Considering the correspondence of the minimum catch size of trammel nets and traps with the size at first sexual maturity, we can argue that static gear operate mainly on the mature stock, while trawling gear are not selective for recruits and spawners.

The fullness index (FUI) clearly indicated that cuttlefish caught by trawling are more suitable for diet analysis than those caught by static gear. One explanation could be related to the time set for the traps and nets, sometimes lasting two or three days. Pinczon du Sel *et al.* (2000) pointed out that specimens from traps gave altered results since, being immersed for two days, animals emptied their gut contents. Digestion in *S. officinalis* takes about 20 hours at 15° C (Boucaud-Camou, 1973), always less than a day. Another explanation for those FUI results could be related to reproduction: Pinczon du Sel *et al.* (2000) observed that the repletion ratio was minimal during the reproductive period (around 25%), whereas during the rest of the life cycle it was higher than 50%. These conclusions are in accordance with the results of the study, since mostly static gears are employed during the spawning period.

The results of the diet analysis agree substantially with those obtained by several authors for the same species in coastal waters (Castro & Guerra, 1990; Pinczon du Sel & Daguzan, 1997; Blanc *et al*. 1998; Pinczon du Sel *et al.,* 2000; Mendes Alves *et al*., 2006). Crabs and bony fish species were the most important prey in the diet. In particular, species of the crab family Portunidae (*Liocarcinus* sp.) were the main prey, which is similar to the findings of Pinczon du Sel *et al.* (2000). They pointed out the importance of *Carcinus maenas* and *Liocarcinus arcuatus* in the northern Bay of Biscay (France), in the period when *S. officinalis* moves toward coastal waters for reproduction. Unfortunately, during our study most of the otoliths were not analyzed, but the few samples that were analyzed indicated that gobies (family Gobiidae) represent an important food item in this area, which is in accordance with the results of Castro & Guerra (1990), Pinczon du Sel & Daguzan (1997), Pinczon du Sel *et al*. (2000) and Guerra (2006).

Our results do not show significant differences in feeding habits between the sexes at any size, as previously revealed by Castro & Guerra (1990), Pinczon du Sel & Daguzan (1997), Guerra (2006) and Mendes Alves *et al*. (2006). Conversely, a significant change in the diet occurred with growth. In this way, seasonal differences could be linked primarily to cuttlefish size and reproduction (Mendes Alves *et al*., 2006). Osteichthyes appeared mostly in the largest specimens: Pinczon du Sel *et al.* (2000) reported that fishes become an important food item for individuals over 9 cm ML, whereas Castro & Guerra (1990) recorded a significant increase of the occurrence of Gobiidae in ML $\geq$ 12 cm. Specimens of ML > 6.5 cm are sexually maturing or have reached maturity (mainly males) (Guerra & Castro, 1988), therefore the variation of the diet according to size and reproductive period seems to be clear, with an increase of fish and cephalopods and a decrease of crustaceans and "sedentary" prey (bivalves, polychaetes and gastropods) (Mendes Alves *et al*., 2006). The substantial presence of crabs in the diet of smaller cuttlefish can be easily explained by the fact that benthic-dwelling crustaceans might be easier to catch. This shift in the diet can also be associated with higher energy demands (Castro & Guerra, 1990), as well as with an increase in hunting range (Vovk, 1985). Moreover, larger cephalopods are also faster and possess tentacles and resistant arms capable of capturing stronger prey (Mendes Alves *et al.*, 2006).

Pinczon du Sel & Daguzan (1997) concluded that the diet of cuttlefish in Morbihan Bay (France) was not influenced by the fishing gear used, except for traps, where a larger spectrum of prey taxa was found. In the study area, 34 prey taxa from the stomach of cuttlefish were determined, 32 from trawl gear, and 9 taxa from static gear. Only the pipefish *Syngnathus* sp. and the isopod *Synisoma* sp. were not found in cuttlefish from trawl samples, since these taxa typically inhabit vegetated habitats. During spring, trammel nets and traps are set near sea grass meadows, whereas trawlers are obliged to operate 3 NM off on muddy, sandy and detritic bottoms.

Raw data on annual landings collected during this study indicated a decrease in this cephalopod resource from 2010 onwards. In addition, Piccinetti *et al*. (2012) also recorded 2010 as the year with the minimum biomass and abundance values for the period 1996-2010 in the same study area. Landings data also indicate that the cuttlefish stock is exploited predominantly during spring when static gears are also employed. Belcari *et al.* (2002) found that trawling undoubtedly catches smaller specimens that are not mature yet. On the other hand, trammel nets and traps mainly capture spawners. One possible impact of traps, though, may be the high mortality of the eggs attached inside (Arkley *et al.,* 1996; Blanc & Daguzan, 1998).

More recently, artificial substrates for egg collection and hatching control were tested for cephalopod restocking trials in the Adriatic Sea (e.g. Bettoso *et al.,* 2006; Lazzarini *et al.,* 2006; Barile *et al.,* 2013). Thanks to EU projects, the common aim is further development of these structures in order to adopt preservation methods for cephalopods, mainly cuttlefish and squid.

In the northern Adriatic Sea cuttlefish is exploited by Italian, Slovenian and Croatian fleets, where small-scale coastal fisheries show great complexity, with strong socio-economic, cultural and ecological importance. The application of the Galician model, through an interview survey of the fishing sector personnel in order to estimate catch and catch per unit effort (CPUE), would be very useful for a correct evaluation of fishing effort (for details see Rocha *et al*., 2006). This method, coupled with programmes already in progress for trawl surveys (e.g. MEDITS, see Piccinetti *et al.,* 2012), would be useful for the preparation of specific management plans for cuttlefish exploitation. The contribution of this paper, which provides new insights on the biological parameters of this species in relation to the main fishing gears employed in the northern Adriatic Sea, could provide a basis for future investigations of this resource in the area.

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