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## Seasonal dynamics of small-scale fisheries in the Adriatic Sea

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### Abstract

The seasonal dynamics of the main set gears used in Adriatic small-scale fisheries (SSFs) - gillnets, trammel nets, and traps - was assessed by analyzing wide array of data including landings, fishing effort, catch composition, length-frequency distribution, and economic value of the landings of target species. Data analysis demonstrated that Adriatic SSFs are diverse, complex and dynamic; that they are active throughout the year; and that they exert a number of important local effects, chiefly the provision of (sea)food and employment. Adriatic SSFs exploit coastal fishing grounds, where the seasonal fluctuation of water column physicochemical parameters strongly influences species abundance and distribution. Accordingly, fishermen use several different types of set gears in the course of the year to catch a pool of target species. Moreover, since they tend to increase the fishing effort when target species concentrate in coastal areas during recruitment or spawning, landings peak in such periods and often include a large portion of juveniles and/or spawners. The study highlighted that modulation of the fishing effort is based on inadequate data and statistics, also given the limited use of routine monitoring programs. The knowledge gap is still a major constraint for most Adriatic countries that induces SSF marginalization and limits their value.

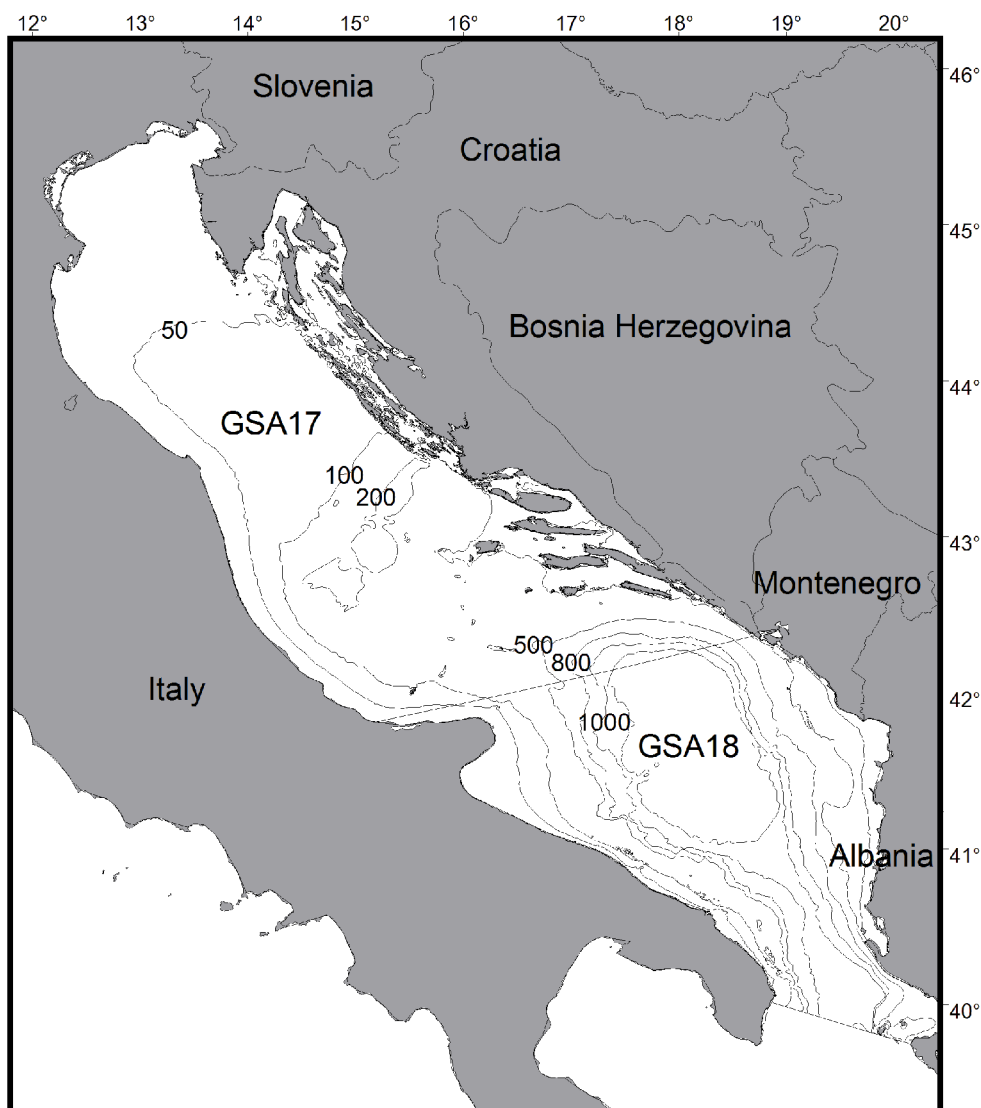
**Keywords:** Adriatic Sea, small-scale fishery, passive gears, fishing effort, landings.

### Introduction

There is no commonly agreed EU definition of small-scale fisheries (SSFs). In the framework of the Common Fisheries Policy, “small-scale coastal fishing” is formally defined for the purposes of the European Fisheries Fund (Regulation 1198/2006) as “fishing carried out by fishing vessels of an overall length of less than 12 m and not using towed gear”. SSFs contribute about half of the world catches in terms of absolute amount and two-thirds of the fish destined for direct human consumption (FAO, 2015). Small-scale fishing fleets account for more than 80% of fleets in the world, in Europe, and in the Mediterranean (European Commission, 2002; Guyader *et al.*, 2007). In the Adriatic Sea, most SSFs exploit areas that

can be reached in a few hours from the home harbor (Bastardie *et al.*, 2017). Adriatic SSFs are active full- or part-time throughout the year and use a wide range of fishing strategies that can be described in terms of target species, fishing gear, fishing grounds, and métiers. Changing resource availability involves frequent seasonal changes of gear and grounds. The wide habitat heterogeneity of the Adriatic Sea - where the seabed is mostly sandy and muddy in the north-western area and mostly rocky in the east and south-west - entails that SSFs employ a variety of passive gears during the year, including gillnets, trammel nets, and traps, to catch a pool of target species in coastal areas (Grati *et al.*, 2010; Fabi & Grati, 2008).

The complexity of Mediterranean SSFs involves that



**Fig. 1:** Study area: the Adriatic Sea subdivided into GFCM Geographical Sub-Area (GSA) 17 and 18.

fleets and their activity are largely described through métiers (Colloca *et al.*, 2004; Tzanatos *et al.*, 2005, 2006, 2013; Duarte *et al.*, 2009; Forcada *et al.*, 2010). Only a very small number of studies have quantified effort and catch (Merino *et al.*, 2008; Rocklin, 2010; Maynou *et al.*, 2011).

This paper provides the natural follow-up of a recent study by the FAO AdriaMed Working Group on SSFs, which has identified the key knowledge gaps and priorities for this sector in the Adriatic (Cobani *et al.*, 2013). The present Working Group consists of fisheries scientists from the six countries with coasts on the Adriatic: Italy, Slovenia, Croatia, Bosnia-Herzegovina, Montenegro, and Albania. The objective of this study is to characterize the seasonal activity patterns of Adriatic SSFs in terms of effort, landings, and revenue based on data obtained from the European Commission's Data Collection Framework (DCF) and national surveys.

## Materials and Methods

### *Study area: Adriatic Sea*

The Adriatic Sea is a semi-enclosed basin in the northern Mediterranean lying between the Italian peninsula and the Balkans. It is divided into two Geographical Sub Areas (hereafter GSAs): a shallower northern area (GSA17) and a deeper southern area (GSA18), whose maximum depth is 1,233 m. (Fig. 1). The western coast of GSA17 is flat and mostly sandy and muddy, whereas the eastern and western coast of GSA18 is mostly steep and rocky and hosts sensitive marine habitats such as seagrass meadows and coralligenous substrates. The northern and central Adriatic Sea is characterized by an extensive continental shelf and by shallow eutrophic waters, whereas the southern Adriatic shows a narrower continental shelf and a steep continental slope. The Adriatic receives one third

of the freshwater flowing into the Mediterranean and acts as a dilution basin. Due to the marked seasonal fluctuations of environmental forcing, bottom temperatures in coastal waters show strong seasonal variation, from 7° C in winter to 27° C in summer; the variability is much more limited in deeper areas, where values range respectively from 10° C to 18° C at 50m (Russo *et al.*, 2012). The prevailing currents flow counterclockwise from the Strait of Otranto along the eastern coast and then back to the Strait along the western coast. As a consequence, the inflowing water masses from the Ionian Sea are warmer and saltier than the out flowing ones.

### Data collection

The seasonal dynamics of Adriatic SSFs was examined by assessing the three main set gears that are commonly used by fishermen from all six Adriatic countries, i.e. gillnets, trammel nets and traps. Coordination with the AdriaMed project allowed using the FAO data for Italy, Slovenia, Croatia, Montenegro and Albania. Since Italy spans two GSA (GSA17 and GSA18), the data for Italy are reported separately for each GSA. Data sources included the DCF for EU Member States and national projects for non-EU countries. The data collected for analysis and their sources are summarized in Table 1. To obtain an exhaustive and reliable dataset, the time frame selected for the study was 2013-2014. Data for each month and season were obtained as follows: i) if such data were available for both years, we used their average; ii) if they were available for a single year, they were assumed to apply to both years. Based on our experience and on observations made by other researchers in other areas (Colloca *et al.*, 2004), we felt that this approach was suitable and sufficiently robust to describe the seasonal dynamics of SSFs in the Adriatic Sea. Notably, the strong seasonal variation in bottom temperature influences species abundance and distribution, driving the succession of fishing techniques, which is almost the same every year.

### Data analysis

The fishing effort was calculated as the number of active vessels using gillnets, trammel nets, and traps each month. Landing composition was calculated by species for the whole period (2013-2014) as a percentage of the weight of the pool of “other species”. Landings were recorded as kilograms of target species caught by each gear and landed each month. Size-frequency distributions were computed on a seasonal basis for each target species and set gear. The value of landings (in Euros) and the average selling price per unit weight (€kg<sup>-1</sup>) of the main target species were calculated for each month and set gear.

### Results

#### Fishing seasons

Analysis of fishing activity showed that gillnets, trammel nets, and traps were used on a seasonal basis to target a pool of species (Table 2).

In Italy (GSA18, southern Adriatic) trammel nets and gillnets were used all year round to catch cuttlefish (*Sepia officinalis*) and the striped red mullet (*Mullus surmuletus*), while the spottail mantis shrimp (*Squilla mantis*) was targeted with trammel nets all year round and with gillnets in January-February and June-October (Table 2). In GSA17 (Italy; northern and central Adriatic) gillnets were used from April to January to target common sole (*Solea solea*) and from July to December for the spottail mantis shrimp; traps for the gastropod *Tritia mutabilis* were used from November to May (the fishing season laid down by local regulations) and cuttlefish traps were set in spring-summer during the spawning period. In Slovenia gillnets were used to target hake (*Merluccius merluccius*) in spring, common sole from September to December, Atlantic mackerel (*Scombers scombrus*) from April to November and the gilthead sea bream (*Sparus aurata*) from August to January. Trammel nets were used

**Table 1.** Data collected for the vessels using gillnets, trammel nets and traps in the Adriatic Sea in 2013-2014 and data sources. DCF = Data Collection Framework; NP = National Projects.

Time scale	Countries	Italy	Slovenia	Croatia	Montenegro	Albania
	Data source	DCF	DCF	DCF	NP	NP
Year	Landing composition	x	x	x	x	
Season	Size distribution of target species	x	x	x		
Month	Gear/species	x	x	x	x	x
	No. vessels	x	x			
	Landing biomass	x	x	x		
	Value of landings	x	x			
	Selling price / kg	x	x			

**Table 2.** Fishing seasons of the main target species of Adriatic SSFs. G = gillnet, T = trammel net, P = traps, Cro = Croatia, Alb = Albania, Slo = Slovenia, Ita17 = Italy GSA17, Ita18 = Italy GSA18.

Target species	Months												Areas
	1	2	3	4	5	6	7	8	9	10	11	12	
<i>M. merluccius</i>	G	G	G	G	G	G	G	G	G	G	G	G	Cro
<i>M. merluccius</i>			G	G	G	G							Alb
<i>M. merluccius</i>				G	G	G							Slo
<i>S. solea</i>	T	T									T	T	Cro
<i>S. solea</i>	G			G	G	G	G	G	G	G	G	G	Ita17
<i>S. solea</i>	T	T	T	T	T	T	T	T	GT	GT	GT	GT	Slo
<i>S. officinalis</i>	T	T	T	T	T	T							Cro
<i>S. officinalis</i>	GT	GT	GT	GT	GT	GT	GT	GT	GT	GT	GT	GT	Ita18
<i>S. officinalis</i>				P	P	P	P	P					Ita17
<i>S. officinalis</i>			TP	T	T	T					T	T	Slo
<i>S. officinalis</i>				P	P	P							Alb
<i>M. surmulets</i>					T	T	T						Alb
<i>M. surmulets</i>	GT	GT	GT	GT	GT	GT	GT	GT	GT	GT	GT	GT	Ita18
<i>M. surmulets</i>	T	T	T	T	T				T	T	T	T	Cro
<i>O. vulgaris</i>	P	P	P	P	P	P	P	P	P	P	P	P	Cro
<i>S. mantis</i>	GT	GT	T	T	T	GT	GT	GT	GT	GT	T	T	Ita18
<i>S. mantis</i>							G	G	G	G	G	G	Ita17
<i>S. mantis</i>					P	P	P	P	P	P			Slo
<i>T. mutabilis</i>	P	P	P	P	P						P	P	Ita17
<i>S. scombrus</i>				G	G	G	G	G	G	G	G		Slo
<i>P. kerathurus</i>					T	T							Alb
<i>S. aurata</i>											G	G	Alb
<i>S. aurata</i>	GT							GT	GT	GT	GT	GT	Slo

to catch common sole all year round and cuttlefish in spring and winter. Traps were used to target cuttlefish in March and the spottail mantis shrimp from May to October. In Croatia, a special type of gillnet was used to catch hake all year round, while different types of trammel nets were employed to target common sole from November to February, cuttlefish in winter-spring, and the striped red mullet from September to May. The first two species are both fished during their spawning season. Traps are used all year round, usually to target octopus (*Octopus vulgaris*).

In Albania gillnets were used from March to June to target hake and in winter to fish the gilthead sea bream, whereas trammel nets were used in spring for the striped red mullet and the caramote prawn (*Penaeus kerathurus*). Traps were used in spring to catch cuttlefish.

### Fishing effort

#### Gillnets

In Italy, gillnet use in GSA17 displayed a marked

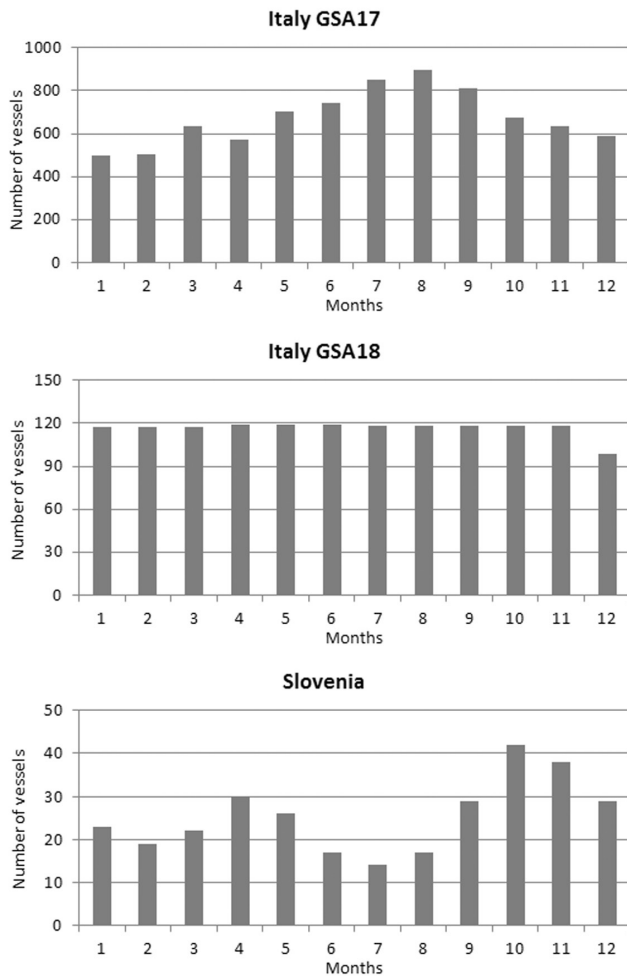


Fig. 2: Number of active vessels using gillnets.

seasonality, increasing from a minimum in January (499 vessels), peaking in August (894 vessels), and then decreasing in the following months (Fig. 2). In contrast, in GSA18 the fishing effort was stable (around 120 vessels all year round) with the exception of December, when it fell by about 20% (99 vessels).

Analysis of the fishing effort of Slovenian gillnetters showed that there were two main seasons, one in spring, at the time of hake season (30 vessels in April), and another in summer-autumn (42 vessels in October), when mackerel and the gilthead sea bream were the main target species.

#### Trammel nets

The fishing effort of Italian trammel netters in GSA18 showed an increase in the first half of the year (from 211 vessels in January to 304 in May-June) and a decline in the second half (from 230 vessels in July through September to 97 in November-December; Fig. 3). Conversely, the Slovenian fishing effort exhibited an opposite trend, with a reduction from 37 vessels in January to 16 in June and an increase from 22 vessels in July to 46 in November.

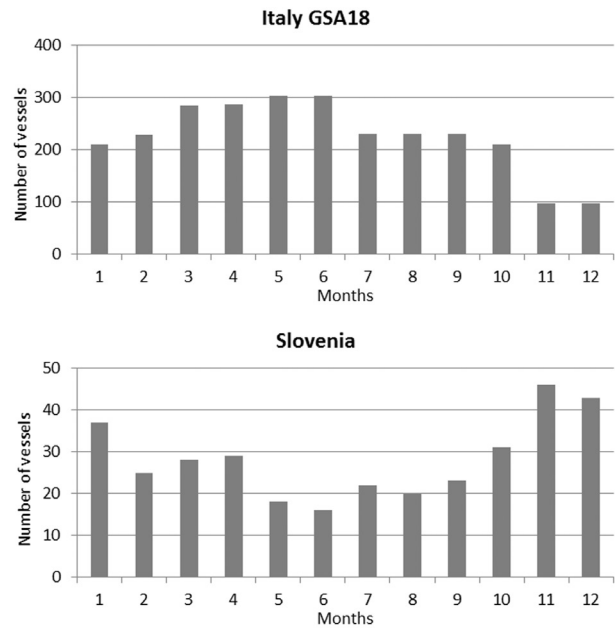


Fig. 3: Number of active vessels using trammel nets.

#### Traps

In Italy the fishing effort in GSA17 exhibited a clear seasonality and was especially intense in spring (407 vessels in May), due to the concurrence of the spawning season of cuttlefish (targeted with pots) and the presence of *T. mutabilis* (targeted with basket traps; Fig. 4).

Albanian fishermen use two types of traps: concrete pots for cuttlefish and stationary uncovered pound nets (stavnik) for pelagic fish. Concrete pots were used in spring during the cuttlefish spawning season by most Albanian SSFs, while stavnik were used on average by 18 vessels.

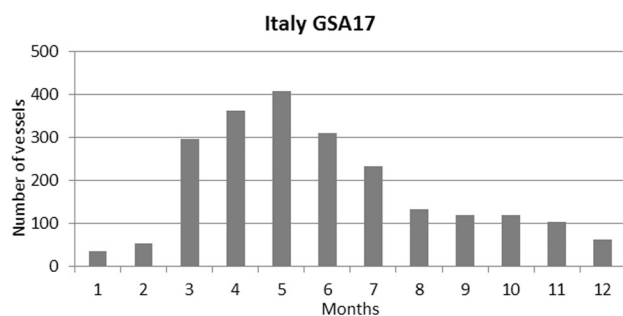
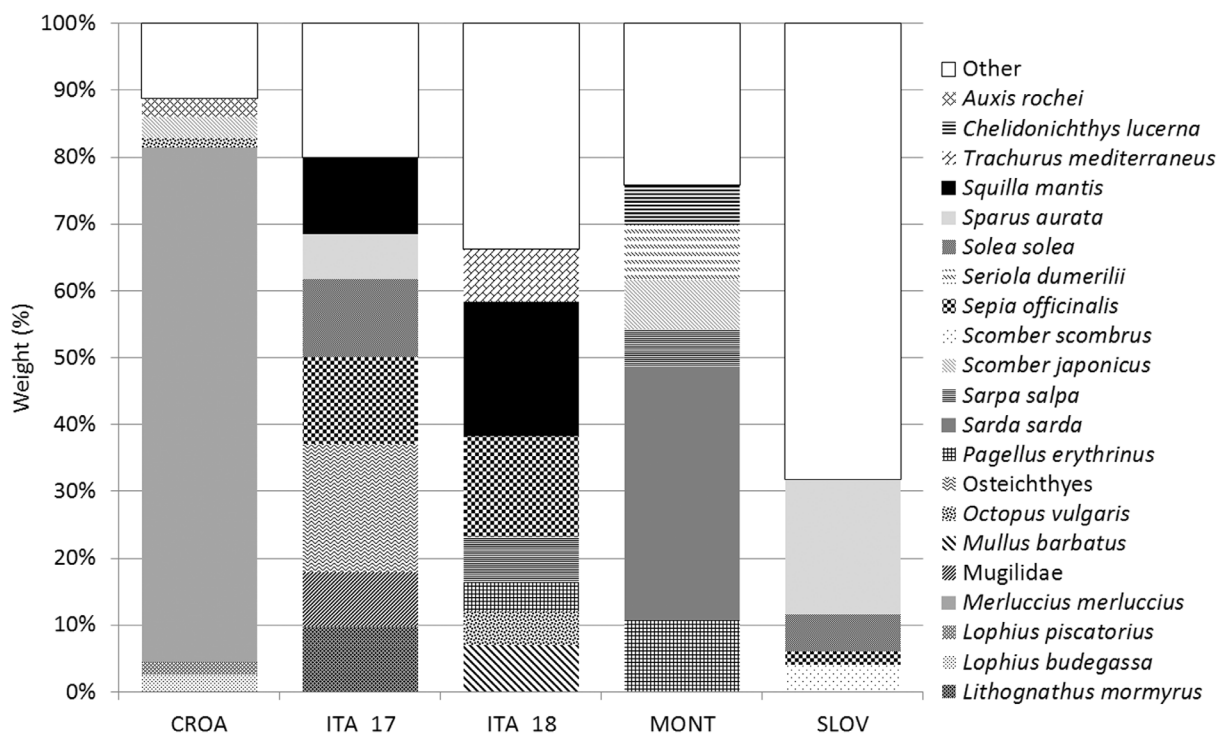


Fig. 4: Number of active vessels using traps.

#### Composition of landings

##### Gillnets

In Croatia, landings were dominated by hake (77%) followed by *Scomber japonicus* (11%; Fig. 5).



**Fig. 5:** Composition of gillnet landings. CROA = Croatia; ITA\_17 = Italy GSA17; ITA\_18 = Italy GSA18; MONT = Montenegro; SLOV = Slovenia.

In the Italian portion of GSA17 three species accounted for more than 10%: cuttlefish, common sole, and the spottail mantis shrimp. In GSA18 the spottail mantis shrimp (20%) and cuttlefish (15%) were predominant, while “other species” accounted for less than 10% and included 63 taxa.

In Montenegro Atlantic bonito (*Sarda sarda*) accounted for 38% of landings, followed by common pandora (*Pagellus erythrinus*, 11%) and great amberjack (*Seriola dumerilii*, 8%). In Slovenia the gilthead seabream made up 20% of landings followed by common sole (6%) and mackerel (4%).

#### Trammel nets

In Croatia’s rocky bottom areas, trammel nets caught a diverse pool of species, predominantly the gilthead sea bream (19%), cuttlefish (14%), octopus (13%), and salema (*Sarpa salpa*, 10%; Fig. 6). Common sole accounted for 83% of landings in the soft bottom areas of the Istria Peninsula.

In Italy, a large fraction of landings in GSA18 was represented by common cuttlefish (18%) and octopus; (12%), followed by *Scorpaena porcus* (9%) and Mugilidae species (6%). Here, too, the “other species” included 63 taxa.

In Montenegro Atlantic bonito (43%) was the predominant species in trammel nets, as in the case of gillnets, followed by red mullet (15%), great amberjack (12%) and bullet mackerel (*Auxis rochei*; 11%). Common sole dominated landings in Slovenia (36%) as it did in Croatia.

#### Traps

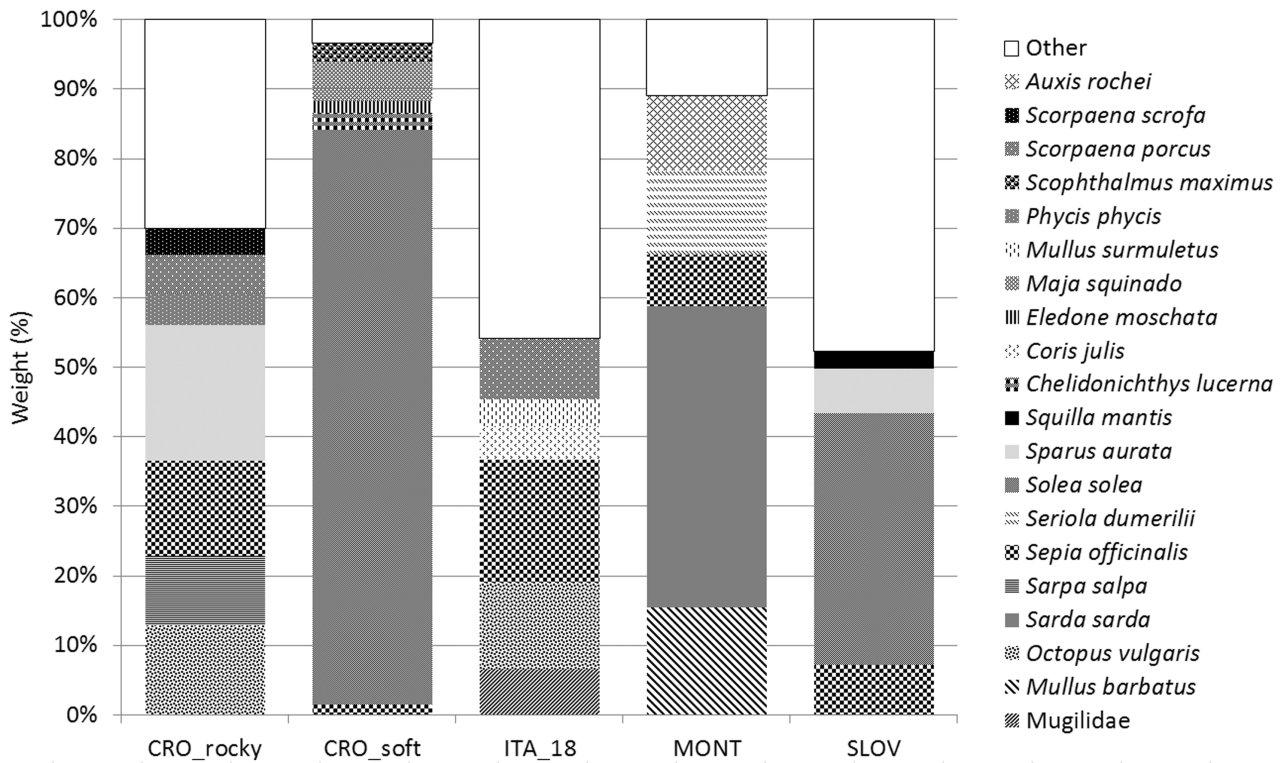
The species composition of trap landings underscored the high species selectivity of this group of gears (Fig. 7). In Italy, *S. officinalis* and *T. mutabilis* made up respectively 81% and 100% of pot and basket trap landings in GSA17. In Slovenia *S. mantis* accounted for 65% of trap landings followed by *S. officinalis* (5%). In Croatia, *O. vulgaris* (76%) was the predominant species followed by Conger conger (conger eel; 5%).

#### Biomass of landings

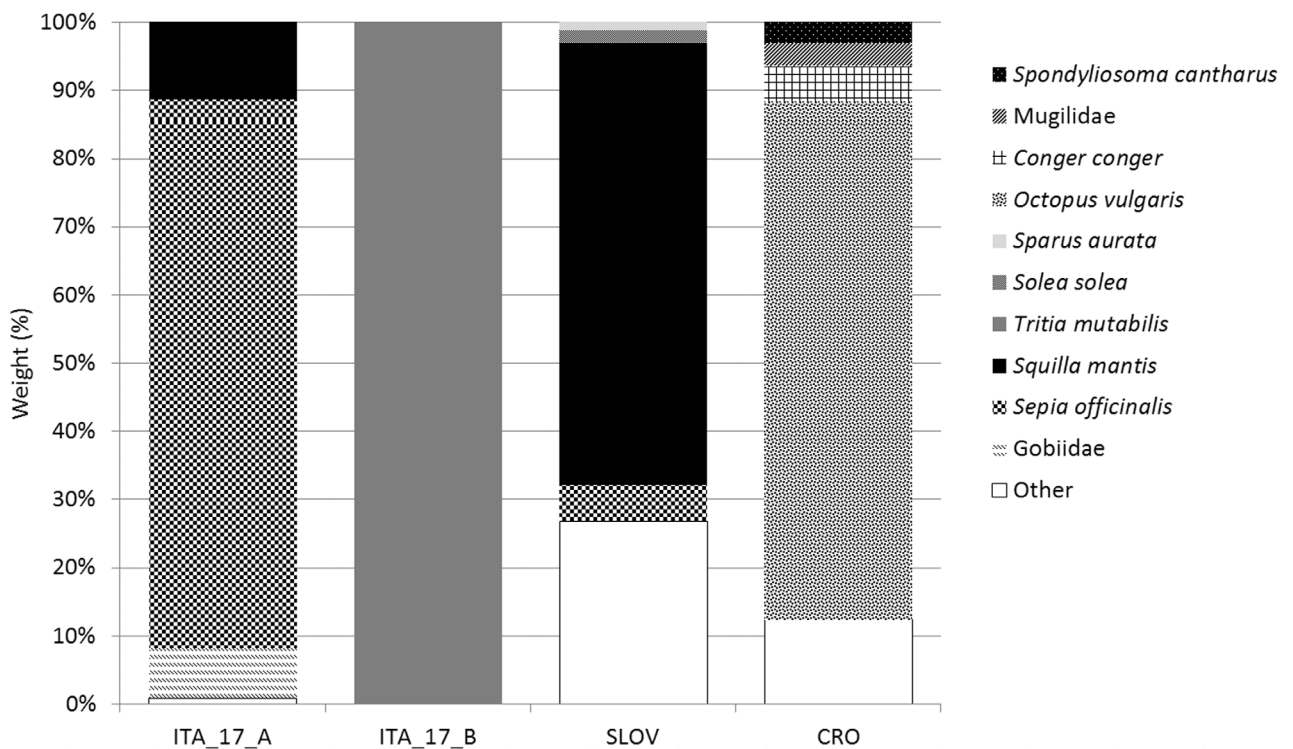
##### Gillnets

In general, the landing biomass data showed a marked seasonality that varied among areas and species. In Croatia, hake was landed throughout the year with a maximum in June (6,030 kg) and a minimum in February (2,390 kg; Fig. 8).

In Italy, the landings of common sole and spottail mantis shrimp in GSA17 showed similar trends, with maxima in August (56,020 and 71,680 kg, respectively) and minima in April (2,570 and 2,620 kg, respectively). In GSA18 landings of spottail mantis shrimp were highest in summer, peaking in September (9,000 kg), whereas cuttlefish showed a peak in May (112,650 kg). In the same area, the striped red mullet was landed throughout the year, but it was most abundant from April to November (maximum in October: 30,390 kg).



**Fig. 6:** Composition of trammel net landings. CRO\_rocky = Croatia rocky bottoms; CRO\_soft = Croatia soft bottoms; ITA\_18 = Italy GSA18; MONT = Montenegro; SLOV = Slovenia.



**Fig. 7:** Composition of traps landings. ITA\_17\_A = Italy GSA17 traps for *S. officinalis*; ITA\_17\_B = Italy GSA17 traps for *T. mutabilis*; SLOV = Slovenia; CRO = Croatia.



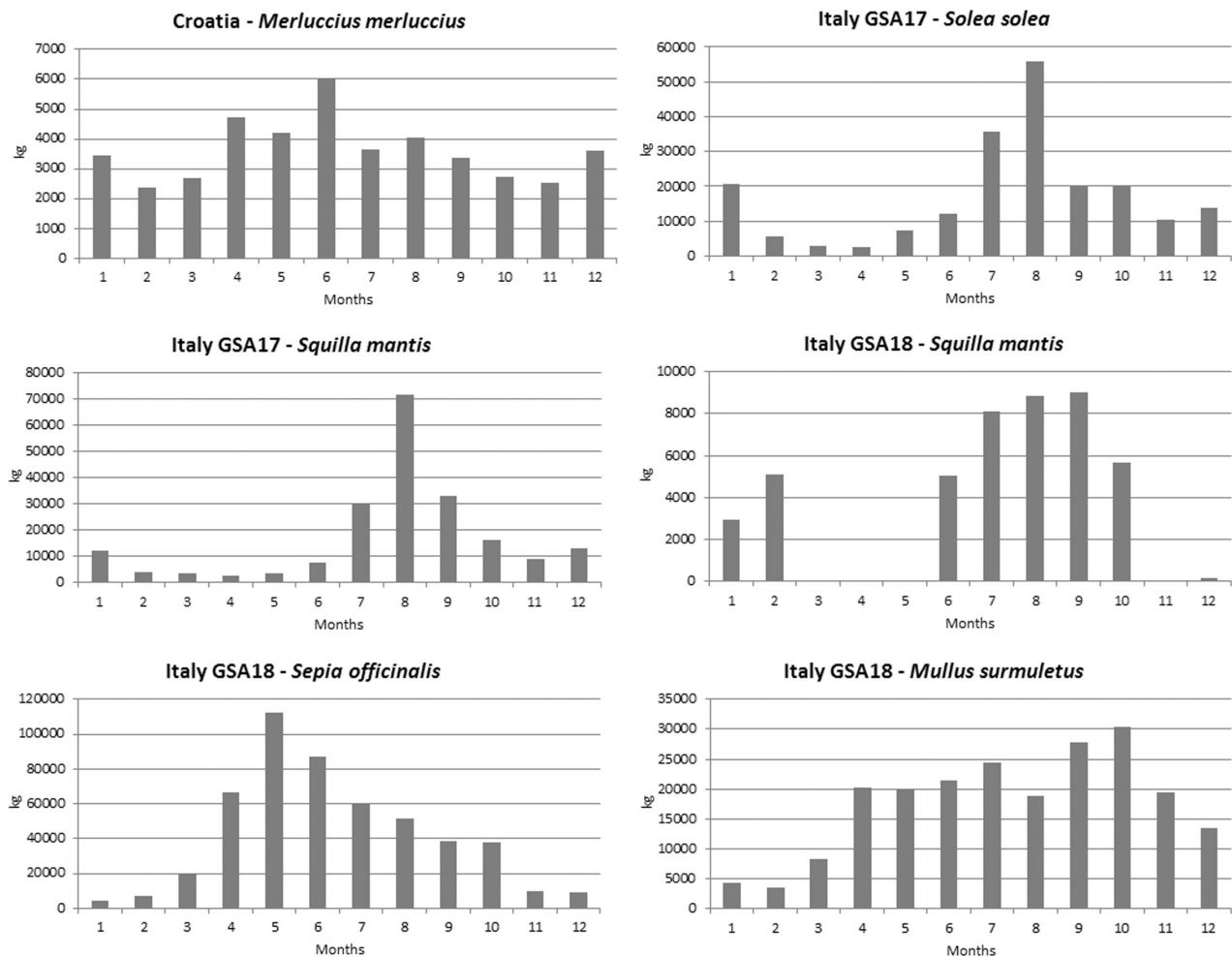


Fig. 8: Biomass of gillnet landings.

### Trammel nets

In Croatia, landing biomass values were highest in winter-spring for cuttlefish (maximum in April: 20,580 kg), in autumn-winter for common sole (maximum in December: 3,550 kg), and in winter-early spring for the striped red mullet (maximum in April: 188 kg) (Fig. 9). A reduction in summer was due to temporary restrictions on trammel net use. In Italy, the landing biomass in GSA18 showed similar trends for *S. officinalis*, *S. mantis*, and *M. surmuletus*, which were landed throughout the year with peaks all in June (9,910, 2,530, and 5,280 kg, respectively) and the lowest values in February. In Slovenia common sole was caught almost exclusively in November (4,820 kg) and December (4,145 kg), and the gilthead sea bream almost exclusively in October (2,043 kg).

### Traps

In Italy, cuttlefish landings in GSA17 were concentrated in spring, during the inshore spawning migration, and reached a maximum of 266,100 kg in May (Fig. 10).

In Croatia, landings of octopus followed a clear seasonal trend with a peak in June (8,097 kg) and a trough in September (2,424 kg). In Slovenia the trap landing data showed a summer fishing season for *S. mantis* (10 kg in September), whereas *S. officinalis* was caught only in March (8 kg).

### Landing biomass per vessel

#### Gillnets

In Italy (GSA17), the landing biomass values showed a similar trend for *S. solea* and *S. mantis*, with a peak in August (*S. solea*: 62.7 kg/vessel; *S. mantis*: 80.2 kg/vessel), and lower values in February-June (Fig. 11). In GSA18 the landing biomass of *S. officinalis* was highest in May (946.7 kg/vessel) and declined in subsequent months (Fig. 11). In this area the biomass values of *M. surmuletus* increased from February (30.5 kg/vessel) to October (257.5 kg/vessel), whereas the yields of *S. mantis* fluctuated over the year, peaking in September (76.6 kg/vessel).

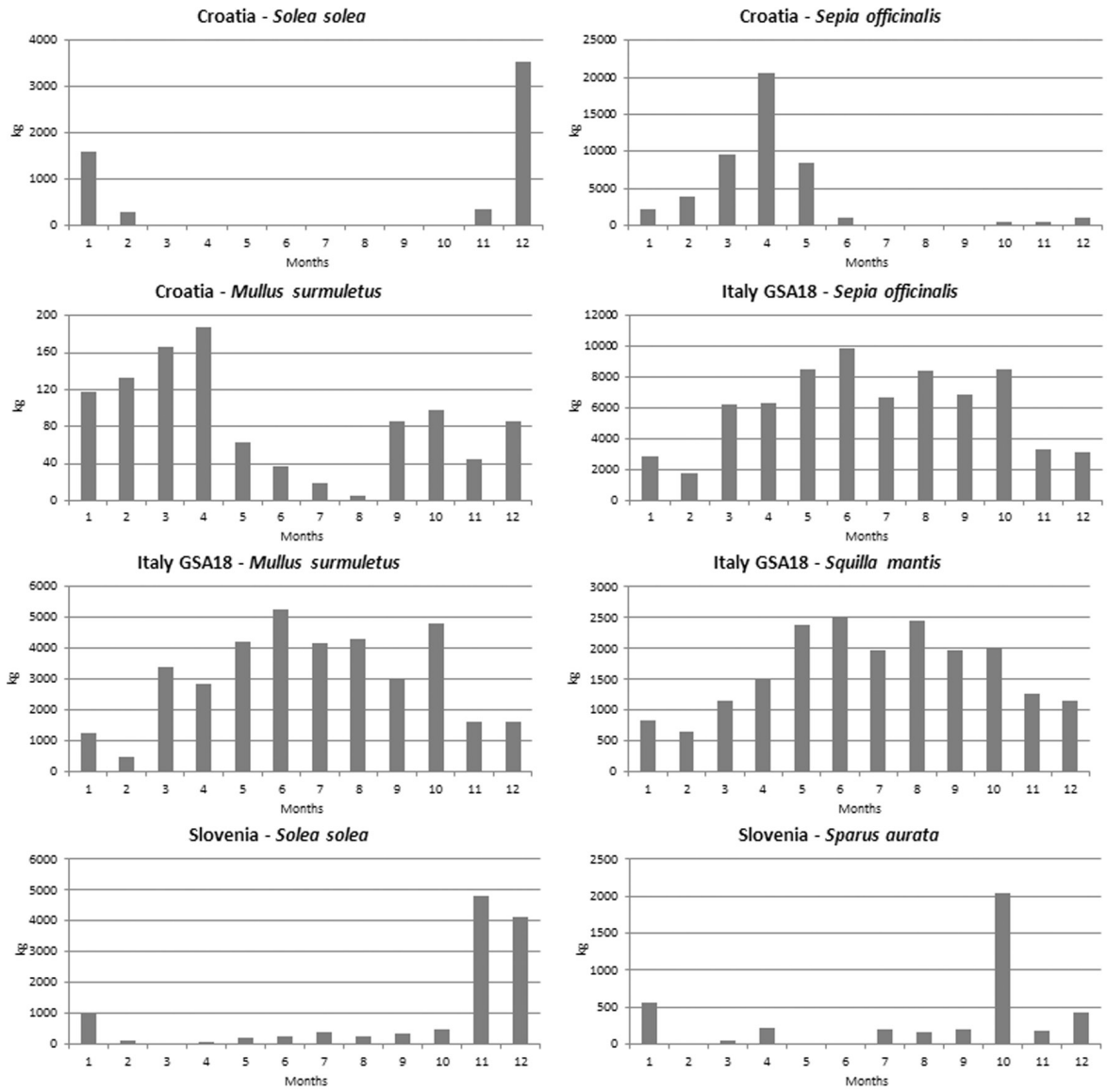


Fig. 9: Biomass of trammel net landings.

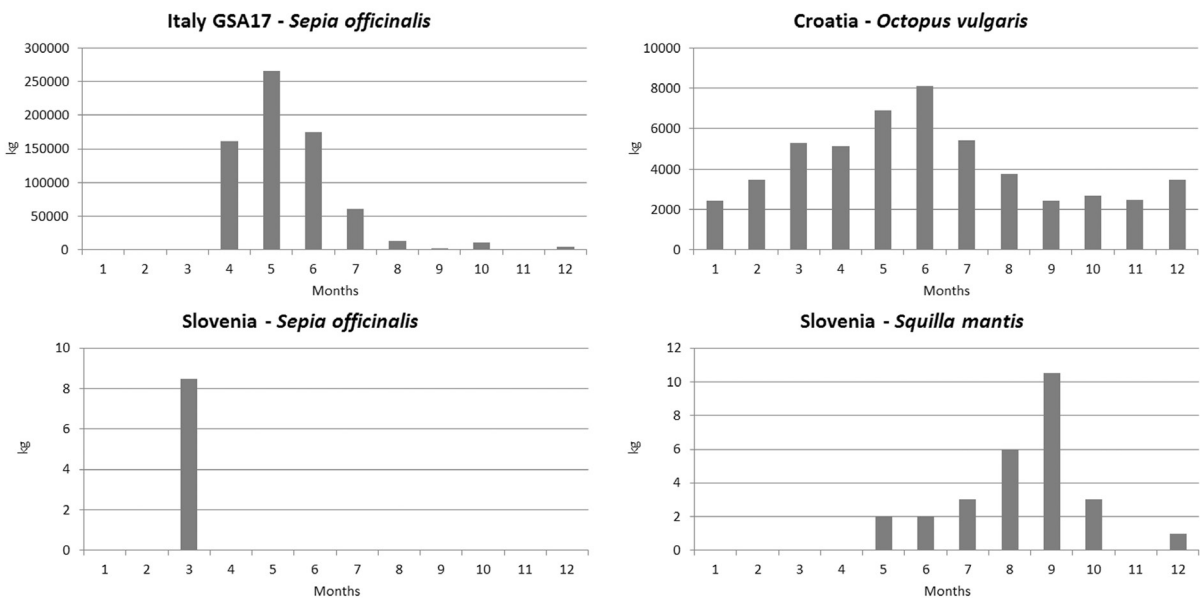


Fig. 10: Biomass of traps landings.

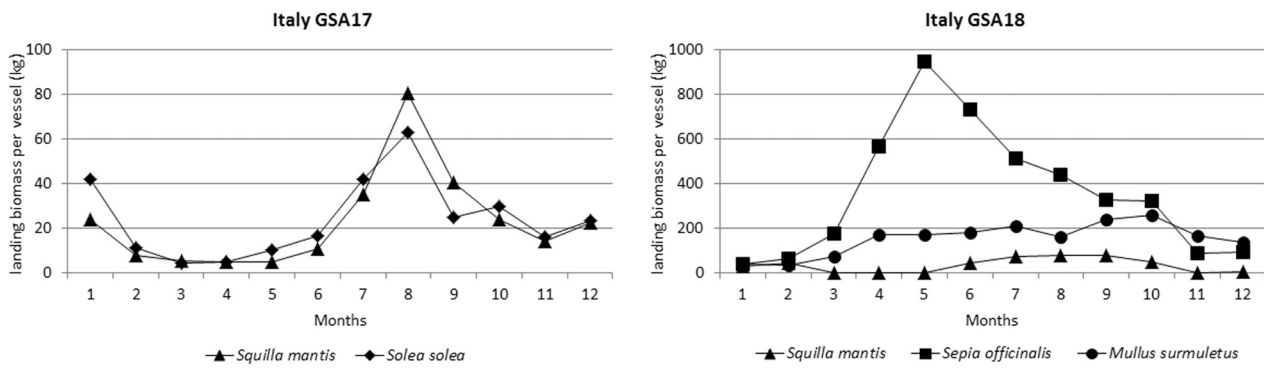


Fig. 11: Gillnet landing biomass per vessel for the main target species.

### Trammel nets

In Slovenia, the landing biomass data showed that autumn was the main fishing season for *S. solea* and *S. aurata*, with peaks in November (104.7 kg/vessel) and October (65.9 kg/vessel), respectively (Fig. 12).

In Italy, the yields of the three main target species (*S. mantis*, *S. officinalis*, and *M. surmuletus*) shared a similar trend in GSA18, with rising values from winter to autumn (Fig. 12). In particular, the landing biomass was highest in October for *S. officinalis* and *M. surmuletus* (40.2 and 22.8 kg/vessel, respectively) and in November for *S. mantis* (13.2 kg/vessel).

### Traps

In Italy (GSA17) the *S. officinalis* landing biomass showed a clear seasonal trend with a maximum in May (653.0 kg/vessel) in correspondence to the spawning period (Fig. 13).

### Size structure of landings

#### Gillnets

In Croatia hake landings showed a similar size structure all year round, with total length (TL) mostly ranging from 25 cm to 44 cm (Fig. 14).

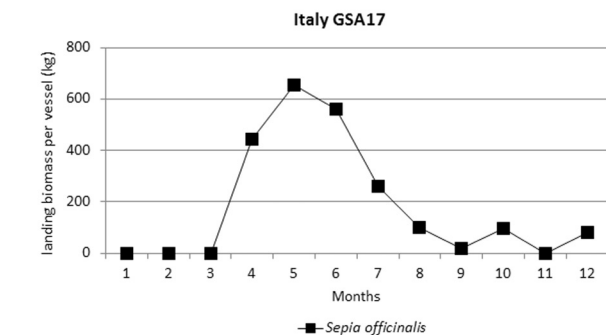


Fig. 13: Trap landing biomass per vessel for *S. officinalis*.

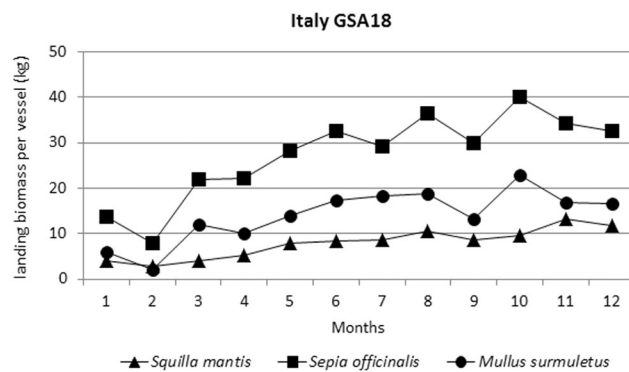
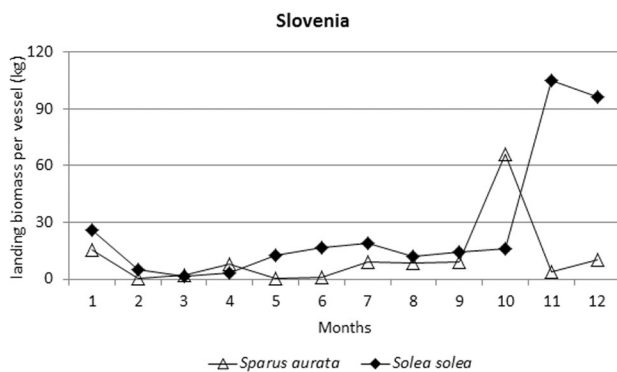
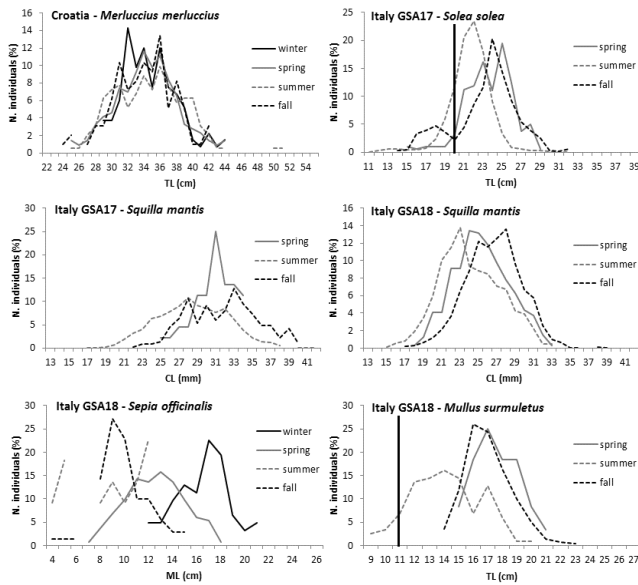


Fig. 12: Trammel net landing biomass per vessel for the main target species.



**Fig. 14:** Size-frequency distributions of gillnet landings. TL = total length; CL = carapace length; ML = mantle length. Vertical lines: minimum landing size.

and by small individuals in summer and autumn (recruitment phase). In this area the size structure of striped red mullet landings clearly showed that smaller individuals were caught in summer and larger individuals in spring and autumn.

#### Trammel nets

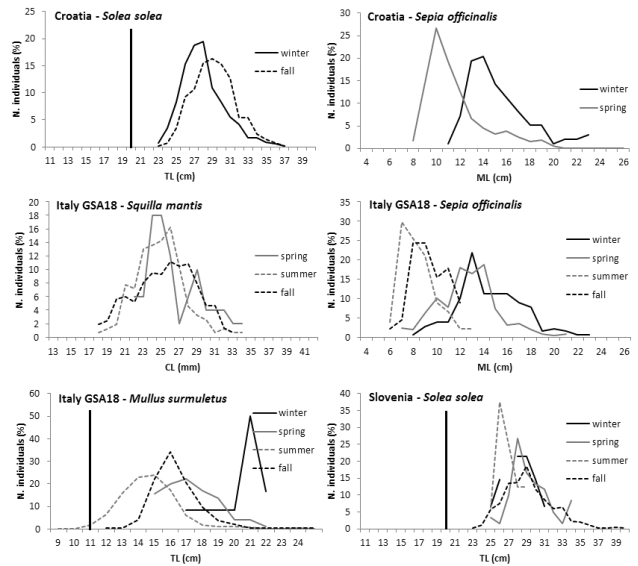
In Croatia the size structure of common sole landings showed a marked seasonality, as the species was caught exclusively in winter and autumn during its spawning season, with a gradual increase in size (Fig. 15). The cuttlefish cohort also showed a clear seasonality, being found in trammel nets exclusively during the inshore spawning migration.

In Italy, the size-frequency distribution of *S. mantis* in GSA18 did not show a clear seasonality, since their size range was quite similar from spring to fall; in contrast, cuttlefish landings reflected a strong seasonality, since large specimens were caught during the spawning period (winter-spring) whereas small individuals were caught in the recruitment phase (summer-autumn). The landings of striped red mullet displayed a seasonal pattern, with increasing sizes from summer to autumn and larger individuals in winter and spring.

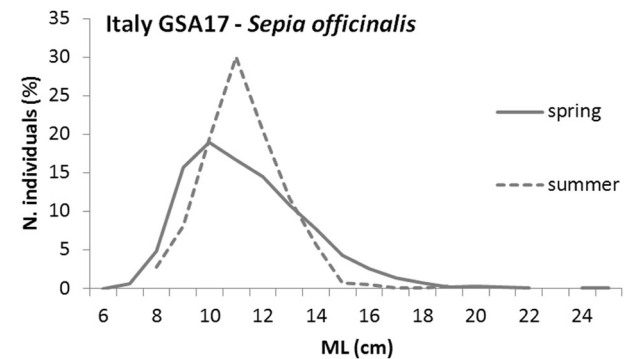
In Slovenia the size distribution of common sole did not show a clear seasonality, as their size range was similar throughout the year.

#### Traps

In Italy (GSA17) cuttlefish traps were laid exclusively during the spawning period; as a result, landings consisted mainly of large specimens both in spring and early summer (Fig. 16).



**Fig. 15:** Size-frequency distributions of trammel net landings. TL = total length; CL = carapace length; ML = mantle length. Vertical lines: minimum landing size.



**Fig. 16:** Size-frequency distribution of trap landings. ML = mantle length.

#### Value of landings

##### Gillnets

In Italy (GSA17) the mean selling price of *S. mantis* was fairly constant throughout the year, ranging from 7.8 €kg<sup>-1</sup> in January to 10.9 €kg<sup>-1</sup> in July, whereas the value of landings peaked in summer (721,365€ in August). The price of common sole from this area was fairly stable throughout the year with the exception of summer, when the lowest price (7.7 €kg<sup>-1</sup> in July and 10.6 €kg<sup>-1</sup> in August) corresponded to the highest value of landings (1,262,234 € in July and 1,553,100 € in August; Fig. 17). In GSA18, striped red mullet landings and their mean price followed the law of supply and demand, prices being highest in March when the product was scarce (16.3 €kg<sup>-1</sup>) and lowest in September (13.7 €kg<sup>-1</sup>) when landings increased; the value of landings peaked in October (129,406€).

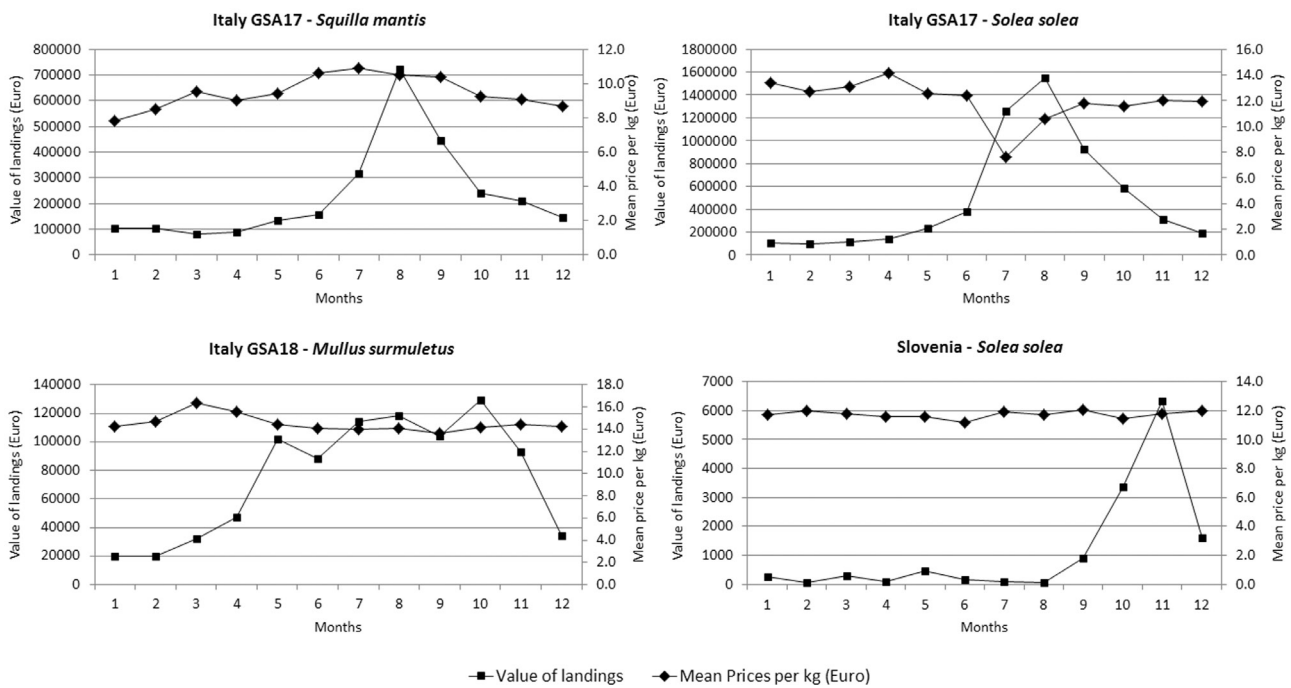


Fig. 17: Total value and selling price per unit weight of gillnet landings.

In Slovenia, the selling price of common sole fluctuated during the year without a clear trend, whereas the value of landings showed a peak in November (6,316€).

*Trammel nets*

In Italy (GSA18) the mean price and the value of landings of striped red mullet followed an opposite trend, as

the price was lowest in summer (minimum in August: 10.1 €kg<sup>-1</sup>), when landings were highest (maximum in September: 104,056€; Fig. 18). The selling price of cuttlefish ranged from 7.5 €kg<sup>-1</sup> in August to 11.2 €kg<sup>-1</sup> in January, whereas the values of landings showed a clear seasonal trend with a maximum in April (354,551€), at

In Slovenia the mean price of common sole increased

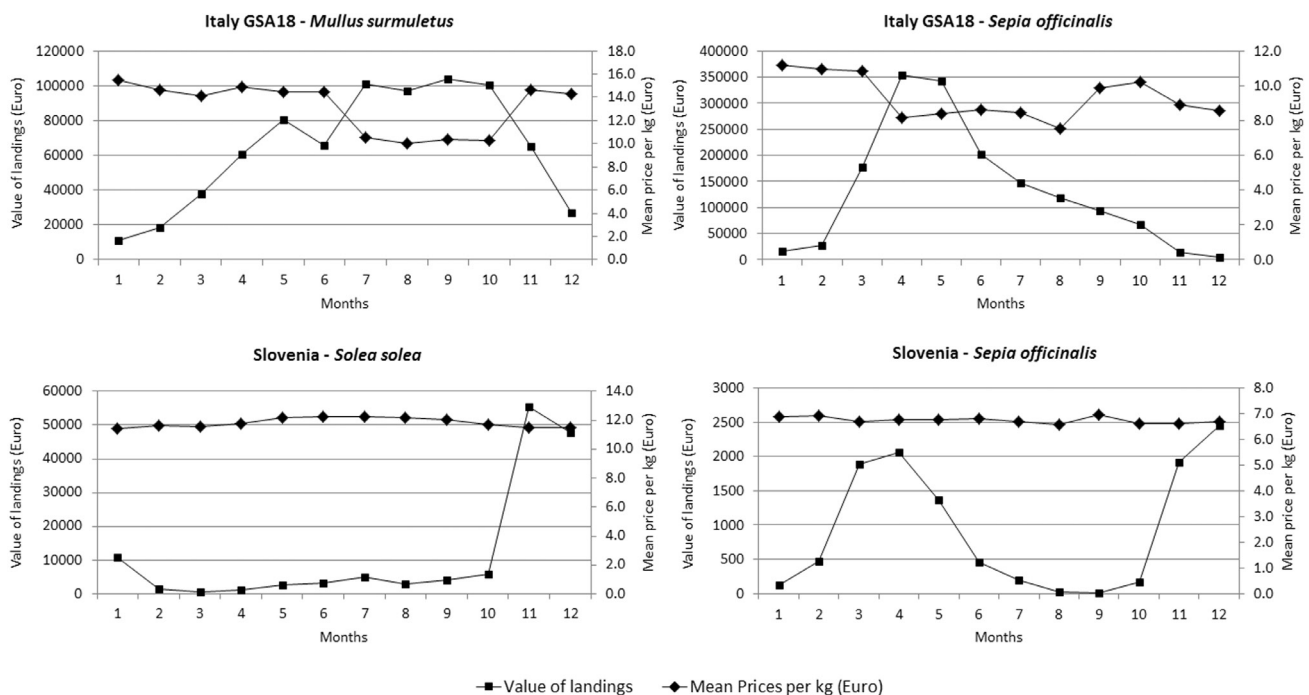


Fig. 18: Total value and selling price per unit weight of trammel net landings.

during the first half of the year (peaking in June at 12.3 €kg<sup>-1</sup>) and declined during the second half, whereas the value of landings showed a peak only in November (55,419€). The value of cuttlefish landings showed two main seasons, spring and autumn (with a peak in December: 2,458€); the selling price did not show marked differences during the year and ranged from 6.6 to 6.9 € kg<sup>-1</sup>.

### Traps

The value of cuttlefish landings in Italy (GSA17) showed a clear seasonality, with a peak in spring (May: 1,503,430€); in contrast, the lowest selling price was recorded at the beginning of the fishing season (March: 5.9 €kg<sup>-1</sup>) and the highest price at the end (August: 8.9 €kg<sup>-1</sup>; Fig. 19).

In Slovenia the value of *S. mantis* landings also showed a marked seasonality, with a peak in September (84.0€), where as the selling price (8.0 €kg<sup>-1</sup>) was stable throughout the fishing season.

### Discussion

Adriatic SSFs are diverse and complex. The variety and marked seasonality of target species and habitat heterogeneity involve frequent gear switches. Adriatic SSFs mostly use gillnets, trammel nets, and traps, which present an assortment of variants in features such as mesh size and material, dimension, shape, also in relation to local customs and traditions.

Gear selection is made both yearly, when the equipment is purchased and/or prepared, and daily, mostly in relation to variables such as the amount and value of recent catches, market demand, weather conditions, and information or rumors about the catches of other fishermen (Forcada *et al.*, 2010). According to a recent study (Leleu *et al.*, 2014), fishing activities are effectively tailored to the behavioral ecology of target species through the adjustment of gears and effort to the seasonal dynamics of the various species.

The analysis of catch composition demonstrated that all the set gears were characterized by high species selec-

tivity (Grati *et al.*, 2010), especially traps, whose target species accounted for more than 65% of their total catch. Even though the present study focused on landings, and did not therefore assess discards, several researchers have highlighted that traps and pots are usually more selective and produce less by catch than other fishing gears, either passive and active (Broadhurst *et al.*, 2007; Suuronen *et al.*, 2012).

Data analysis also documented that in coastal areas, which are characterized by marked seasonal variability and environmental heterogeneity, set gears ensure diversification of fishing tactics (Colloca *et al.*, 2004; Forcada *et al.*, 2010). Flexibility seems to be a key characteristic shared by Adriatic and Mediterranean fisheries (Jabeur *et al.*, 2000; Colloca *et al.*, 2004; Tzanatos *et al.*, 2005; García-Rodríguez *et al.*, 2006; Matić-Skoko *et al.*, 2011). In general, fishermen alternate set gears over the year to optimize yields (Forcada *et al.*, 2010), adapting the fishing effort to the behavior and availability of commercial species, e.g. spawning season and nursery or wintering grounds (Stergiou *et al.*, 2006; Tzanatos *et al.*, 2006). For instance, adult cuttlefish migrate inshore in late winter–early summer and are targeted with several set gears in Italy and Croatia (Fabi *et al.*, 2002), resulting in strong seasonal patterns of landings, catch size structure, and market prices. A pattern has also been reported for hake, striped red mullet, and octopus in Croatia, where seasonal landings reached maxima in correspondence to the peak spawning period, which for all three species occurs in spring (Županović & Jardas, 1989; Tursi & D’Onghia, 1992; Voliani & Pesci, 2017).

The seasonal landing and size-frequency distribution of common sole were in line with recent reports (Grati *et al.*, 2013) and with the notion that the geomorphological and hydrological characteristics of the Adriatic Sea strongly influence the distribution pattern of this species. The present data confirm that in summer young soles largely concentrate on the Italian side of GSA17, where they are caught by Italian gillnetters, whereas older individuals mostly aggregate along the eastern coast in winter and are caught by Croatian and Slovenian trammel nets. Indeed, the whole life cycle of *S. solea* seems to follow

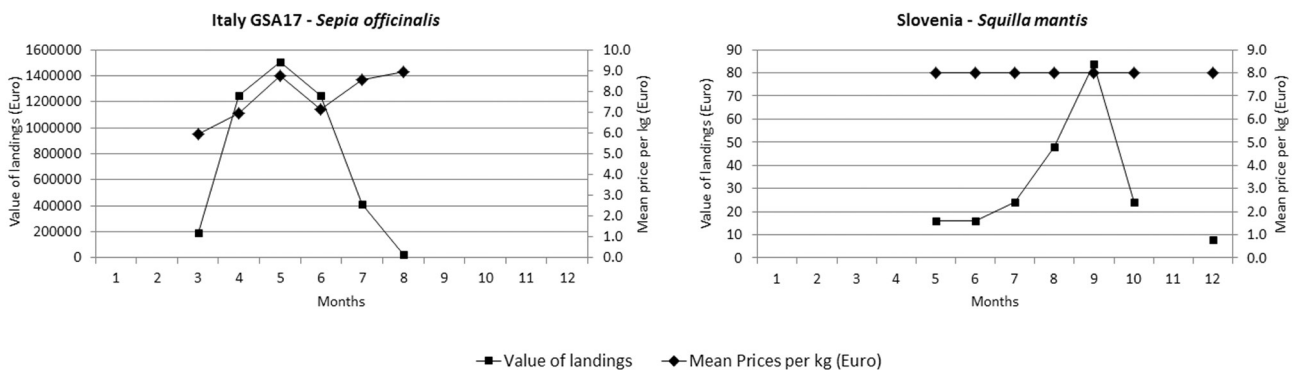


Fig. 19: Total value and selling price per unit weight of traps landings.

the Adriatic circulation and the cyclonic gyres that form in autumn in the northern and central Adriatic, in correspondence to its spawning season (Russo & Artegiani, 1996). As a result of these periodic changes in resource availability, local fish markets are supplied with large quantities of some species for relatively short periods and prices may collapse if supply exceeds demand. However, the spatial and temporal flexibility of SSFs ensures stable total landings and sustained returns throughout the year. Moreover multi-gear fisheries may be less vulnerable to the consequences of climate change on fishery resources (Gamito *et al.*, 2016). The above characteristics provide an added value for consumers, in terms of traceability and quality of fish and seafood products. Notably, SSFs account for a significant quota of total catches and they mostly supply local markets. Price, quality, and safety are main determinants of consumer demand for fish products, and the products offered by SSFs meet all these requirements.

The study also highlighted that a lack of exhaustive data and statistics is still a major constraint for most Adriatic coastal countries, since routine monitoring programs are in place in very few countries (Stagličić *et al.*, 2011). These gaps often have the effect of confining SSFs to a marginal role and undermine the potential for their sustainable growth. In fact, even though passive gears have a limited impact on the environment (being less destructive than towed gears) and on resources (providing higher selectivity than towed gears), they are commonly used in coastal fishing grounds, which include ecologically important habitats such as spawning areas, nursery grounds, feeding areas and migration routes (Grati *et al.*, 2013; Colloca *et al.*, 2015). The ability of SSFs to adapt to the life-cycle changes of target species in the Adriatic Sea involves a further potential impact of these fisheries, especially considering the warming scenario (Azzurro *et al.*, 2011).

With regard to the sustainability of Adriatic SSFs, it is possible to make some considerations on their impact on stocks using a key paradigm of fish population dynamics: the proportion of specimens smaller than the size at first maturity (L50) found in the catch (e.g. Froese, 2004). According to the present findings, the proportion of such specimens of *M. surmuletus*, *S. mantis*, and *S. officinalis* – the three major target species of SSFs – found in the landings was negligible for *S. mantis* fished in Italy (GSA17 and GSA18; carapace length, 21.1 mm in GSA18; Carbonara *et al.*, 2013), regardless of the gear used; the impact on the size structure of cuttlefish (mantle length, 10 cm in GSA17; Manfrin Piccinetti & Giovanardi, 1984) was limited, since it was caught only in winter and spring regardless of area and gear; and the impact on the striped red mullet (TL, 14 cm; Massuti *et al.*, 2005) was low, except for the summer for both gears (trammel and gillnet). Clearly, the actual impact on target populations in terms of harvest rate remains to be assessed case by case and fleet by fleet.

## Conclusions

By providing a wide range of data on the way fishermen select and switch set gears and modulate the fishing effort on a large pool of target species, this study contributes important information towards the assessment of Adriatic SSFs and the study of integrated management approaches.

Adriatic SSFs exploit coastal fishing grounds, where seasonal fluctuations of water column physicochemical parameters exert a marked influence on species abundance; their effect is stronger in the central and northern Adriatic, where strong river runoffs and very shallow bottoms create a steep seasonal gradient in the coastal strip (Marini *et al.*, 2008).

The analysis of landings highlighted clear seasonal trends for the main target species, especially in Italy (GSA17) and Albania, whereas the geomorphological and oceanographic features in Croatia and on the Italian side of GSA18 likely result in a prolonged presence of target species inshore. The high local variability of species abundance and the fishermen's dynamic response, which involves frequent gear switches throughout the year, suggests that the collection of catch and effort data for management purposes should be conducted on a very small scale. Although such high flexibility also enables small-scale fishermen to circumvent restrictions by switching métiers, and may result in an excessive fishing effort on other species or habitats (Tzanatos *et al.*, 2006), assessment of the impact of Adriatic SSFs on the size structure of some target species indicated that they are associated with a more sustainable exploitation pattern compared to other fisheries.

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