

Exploitation patterns of *Octopus vulgaris* in two Mediterranean areas*

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SUMMARY: Exploitation patterns of the common octopus, *Octopus vulgaris*, in two Mediterranean areas were studied in three ports, two in the Thracian Sea (Greece, Eastern Mediterranean) and one in the Catalan Sea (Spain, Western Mediterranean). The study period of one year (July 1998-June 1999) included a monthly collection of data on commercial landings, fishing effort and length distribution of *O. vulgaris*. Many gears exploit this species in both areas. Specialised and highly productive artisanal gears (fyke nets, pots and traps) have been developed. Herein it is shown that: (1) trawls are responsible for most octopus landings; (2) trawls exploit mostly the small and immature individuals while the artisanal fleets exploit the large and mature ones; (3) there is a marked seasonality of catches; (4) there is little or no interaction between the gears fishing octopus, indicating that each gear affects a certain size range; (5) and the octopus specimens from the Greek area are clearly smaller than the ones from the Spanish area. Our results suggest that octopus fisheries require more effective management strategies. The creation of marine harvest refuges may be beneficial.

Key words: octopus, exploitation, Mediterranean Sea, trawling, artisanal gears.

INTRODUCTION

The number of studies on cephalopod populations has increased over the last 25 years and the role of cephalopods in the marine fisheries and their increasing value as a globally exploited resource are highly recognized (Boyle and Boletzky, 1996; Guerra, 1997). Despite these recent advances there is still much to be investigated in order to improve the quality and quantity of the information concerning all aspects of cephalopod studies, from biology to management of their fisheries (cf. Pierce and Guerra, 1994; Caddy, 1997).

In the Mediterranean, cephalopods have traditionally formed a major catch of fisheries. The

Mediterranean is one of the four FAO marine statistical areas with the highest cephalopod catches as a proportion of the total catch of all species (Caddy, 1983). The analyses of statistical records have not shown any remarkable change in cephalopod abundance in the Mediterranean, although cephalopod landings seem to follow regional increases of fishing effort (Worms, 1979; Stergiou, 1988, 1989) and represent a high proportion of the total catch in fishing areas where the continental shelf is more extended and more heavily exploited (Sanchez, 1985; Giovannardi, 1986; Belcari *et al.*, 1986; Belcari and Sartor, 1993; Sartor *et al.*, 1998).

The common octopus, *Octopus vulgaris* Cuvier 1797, is the most important commercially harvested octopus species. The greatest octopus fishery in the world is the Saharan fishery, located off the north-

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west coast of Africa (Hatanaka, 1979; Bravo de Laguna and Balguerías, 1993; Hernández-García, 1995; Guerra, 1997). Other important fisheries exist along the European Atlantic Coast, the Mediterranean Sea, Japanese waters, and off Venezuela (Guerra, 1997). In the Mediterranean, this species is the most commercially important among all cephalopods. It is fished mostly by trawls as a by-catch but other gears are also involved, i.e. beach seines, trammel nets, fyke nets, pots and traps. Despite its importance, there is a lack of analytical studies incorporating the multigear approach needed for the evaluation of multigear fisheries. Most of the studies published on the biology of *O. vulgaris* in the Mediterranean refer to individuals kept in laboratory conditions (Boucaud-Camou *et al.*, 1976; Nixon and Maconnachie, 1988; Villanueva, 1995; Villanueva *et al.*, 1996). A limited number of reports deal with the exploitation of this species by trawls in the Western Mediterranean (Sánchez and Martín, 1993; Quetglas *et al.*, 1998; Sartor *et al.*, 1998). The coastal octopus has the longest history of human exploitation of any cephalopod type (Boyle, 1990). Despite this fact, there exist only two records on the directed artisanal fishing methods of this species in the Mediterranean (Sánchez and Obarti, 1993; Tsangridis *et al.*, 2000).

The aim of this work is to provide a better basis for assessing the fishery structure and the exploitation patterns of *O. vulgaris* in two areas of the Mediterranean (Kavala, Thracian Sea, Greece, Eastern Mediterranean and Barcelona, Catalan Sea, Spain, Western Mediterranean), including all the gears involved and their likely interaction.

MATERIAL AND METHODS

The study was carried out in two fishing areas located in the Provinces of Kavala (Thracian Sea, Greece, Eastern Mediterranean) and Barcelona (Catalan Sea, Spain, Western Mediterranean). The ports of Kavala, Limenas (province of Kavala) and Vilanova (province of Barcelona) were selected for monitoring since in these ports all types of gears involved in the exploitation of *O. vulgaris* are used (Fig. 1).

Fishing fleets

The Greek data for the fishing fleet and gears fishing *O. vulgaris* were mainly collected from the census of the Greek Fishing Fleet, performed in September 1998 by the Ministry of Agriculture. These data were combined with additional information from the regional fisheries offices, the Fisheries Development Company (ETANAL) and the National Statistical Service of Greece (NSSG).

The Spanish data were provided by the Fishermen's Association of Vilanova port (1997), which details the general information about the fleet (number of vessels, gross registered tonnes).

Fishing gears

In the fisheries of Kavala and Limenas, the gears used for catching octopus are trawls, beach seines, fyke nets and occasionally trammel nets. There is a closed season for trawlers and beach seines from June to September. The minimum mesh size

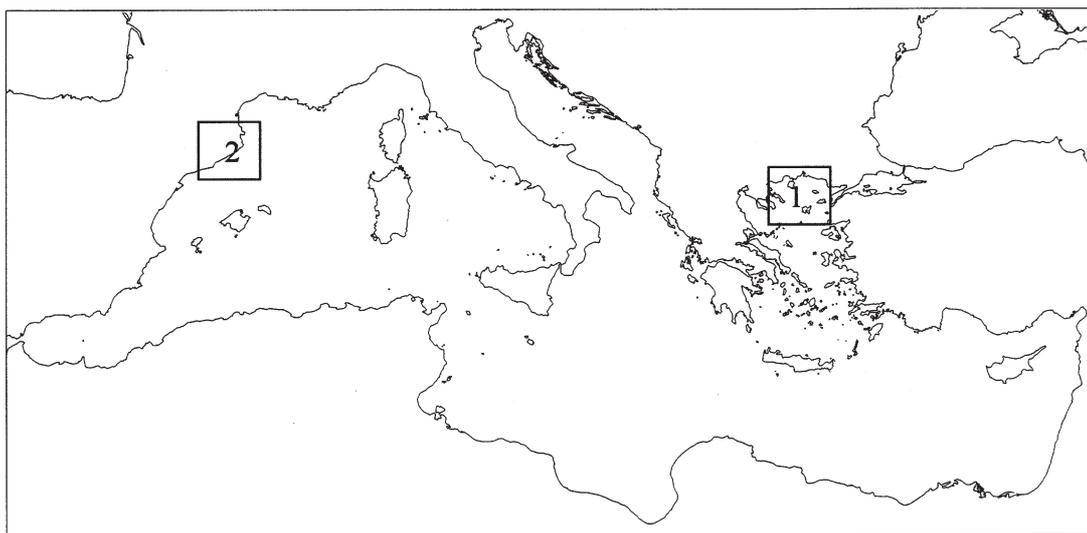


FIG. 1. – Map of the areas studied with the sampling ports: (1) Kavala, Limenas (Thracian Sea); (2) Vilanova (Catalan Sea)

(codend) is 28 mm and 16mm stretched for trawls and beach seines respectively.

Among the artisanals, fyke nets of two or three chambers made of netting with hoops are used for catching almost exclusively octopuses. This method is mainly used in shallow waters of about 8 to 30 m depth, and the fishing season is from October to June.

In Greece, there is no special legislation for cephalopod fisheries.

In the fishery of Vilanova, the gears used for catching octopus are trawls, trammel nets, pots and traps. Since 1994, trawls have followed the EC fishery policy (Regulation 1626/1992). For the artisanal nets, only 1500 m of net per fisherman is allowed. Fishermen can never use more than 4500 m considering that there are three people on board. There is no official legislation for pots (usually 100 pots per fisherman are used). The pots are moored all season in the same place and the fishermen visit them every one or two days depending on the weather. The vessels used for this fishery are usually small, and the fishermen alternate this gear with other artisanal gears depending on the season.

The pot is a specific gear for fishing octopuses (*O. vulgaris*) taking advantage of the behaviour of this species, which searches for a den to shelter in.

The trap is a fixed gear that consists of a cage with easy entrance and difficult exit. To attract the prey, baits are placed in the interior. There is no official legislation for traps, except for fishing the common spiny lobster (*Palinurus elephas*), which is prohibited from September to April.

Sampling and data analysis

Sampling for data on catches and size distribution was performed by month and gear from July 1998 to June 1999. Landings from at least three days per month were expanded to the total fishing days of the month.

The catch per unit of effort (CPUE) was estimated on a fortnightly basis. Fishing effort was estimated as follows:

For artisanal fisheries the units used are kg per fishing day for beach seines; kg/km of net for trammel nets; kg per 100 pairs per fishing day for fyke nets; and kg/100 units for pots and traps.

For trawls the unit used is kg per fishing day.

The size distribution was examined from trawls, beach-seines and fyke nets in the fisheries of Kavala and Limenas; and from trawls, trammel nets, pots and traps in the fishery of Vilanova. 50-400 specimens per gear and month were examined depending on the availability of the species. 2241 individuals were measured in the Greek area and 8584 in the Spanish area. Mantle length was measured to the nearest 0.5 cm. Mean mantle lengths were estimated; corresponding minimum and maximum sizes are also given.

The interaction of the fishing gears using length data was examined by means of the one-way ANOVA. Normal distribution and homogeneity of variance were tested according to the classical methodologies (Shapiro-Wilk, Bartlett and Cochran tests); in the cases of non applicability of the ANOVA, the non-parametric Kruskal-Wallis test was used (Zar, 1984).

RESULTS

Fishing fleets

The fishing fleets which operate in the studied ports can be divided into three groups according to the methods of fishing: trawling, purse seining and artisanal. The trawling gear used exclusively is the otter bottom trawl. According to the composition and characteristics of the fishing fleets in the sampling ports, trawls account for most of the horsepower and gross tonnage registered (Table 1).

Purse seining represents an important fraction of the fishing fleet in the ports of Kavala and Vilanova with 15 and 18 vessels, 4938 and 4697 hp and 977.6 and 485.8 grt respectively. However it is mainly

TABLE 1. – Composition and characteristics of the fishing fleet at the sampling ports. (n = number of vessels; HP = horse power; GRT = gross registered tonnage)

Port	Trawls			Purse-seines			Artisanals		
	n	HP	GRT	n	HP	GRT	n	HP	GRT
Kavala	16	7376	1076	15	4938	977.6	63	3326	284.6
Limenas	-	-	-	2	620	118.4	38	934	79.7
Vilanova	41	6634	1063.1	18	4697	485.8	68	3655	336.1

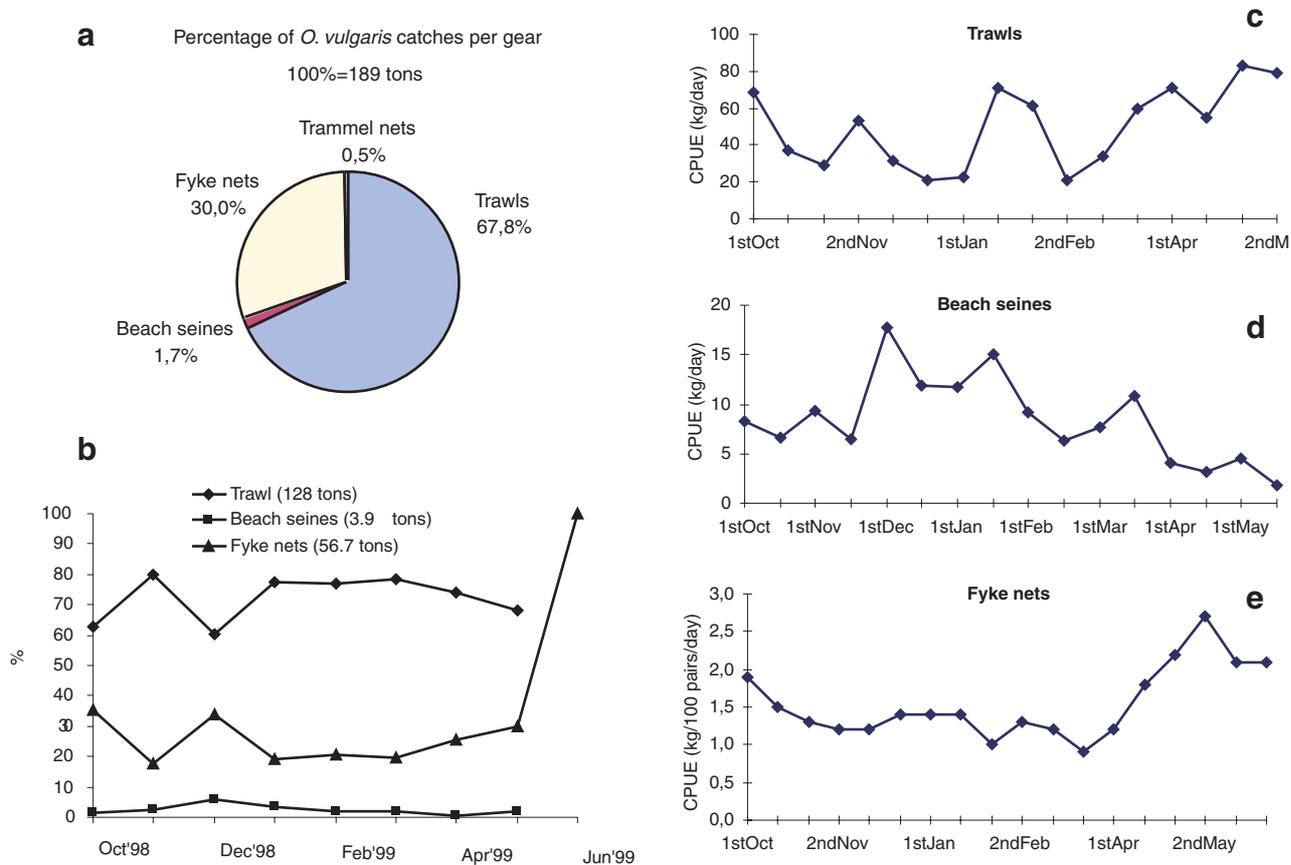


FIG. 2. – (a) Percentage of *O. vulgaris* catches per gear in the period studied; (b) Percentage of *O. vulgaris* monthly catches by gear; (c-e) CPUE of *O. vulgaris* by gear in the period studied. Fisheries of Kavala and Limenas (Thracian Sea).

used to catch small pelagic species. In our study, purse seining is not examined since there is no octopus production.

Artisanal fishery is also important, with a large number of vessels but limited horsepower and tonnage. Especially in the port of Limenas, artisanal fishery (particularly fyke nets in octopus fishing) is the main activity.

Catch composition and CPUE

In the ports of Kavala and Limenas, trawls and fyke nets cover most of the octopus production (67.8% and 30.0%, respectively). Beach seines catch octopus in small quantities (1.7%) and the catch by trammel nets (0.5%) is practically negligible (Fig. 2a).

Catches by fyke nets are high during the whole fishing period. In October and December, the catches by fyke nets reach percentages of more than 30% of the monthly octopus catch. In June they cover 100%, since it is a closed season for trawls and beach seines (Fig. 2b).

It is clear that the CPUE value of trawls is always higher than that of beach seines, ranging from 20 to 85 kg per fishing day. The CPUE value of beach seines, being at lower values, varies from 2 to 18 kg per fishing day. The CPUE for the fyke nets ranges between 1.0 and 2.5 kg/100pairs/day and cannot be compared with the CPUE of trawls and beach seines. The reversed seasonality of octopus CPUE between trawls and beach seines is worth noticing (Figs. 2c-e).

In the port of Vilanova, trawls and pots catch most of the total *O. vulgaris* production (49.0% and 46.0% respectively). Artisanal fishermen also catch *O. vulgaris* with traps and trammel nets (Fig. 3a).

Catches by pots are very high during the period September to December. The catches by the trammel nets and traps are more occasional. The percentage of the monthly catches obtained by the artisanal gears is high during the period between April and June, when it reaches more than 50% of the monthly catches (Fig. 3b).

The evolution of the CPUE during the study period is shown in Figures 3c-f. The trawl CPUE shows a

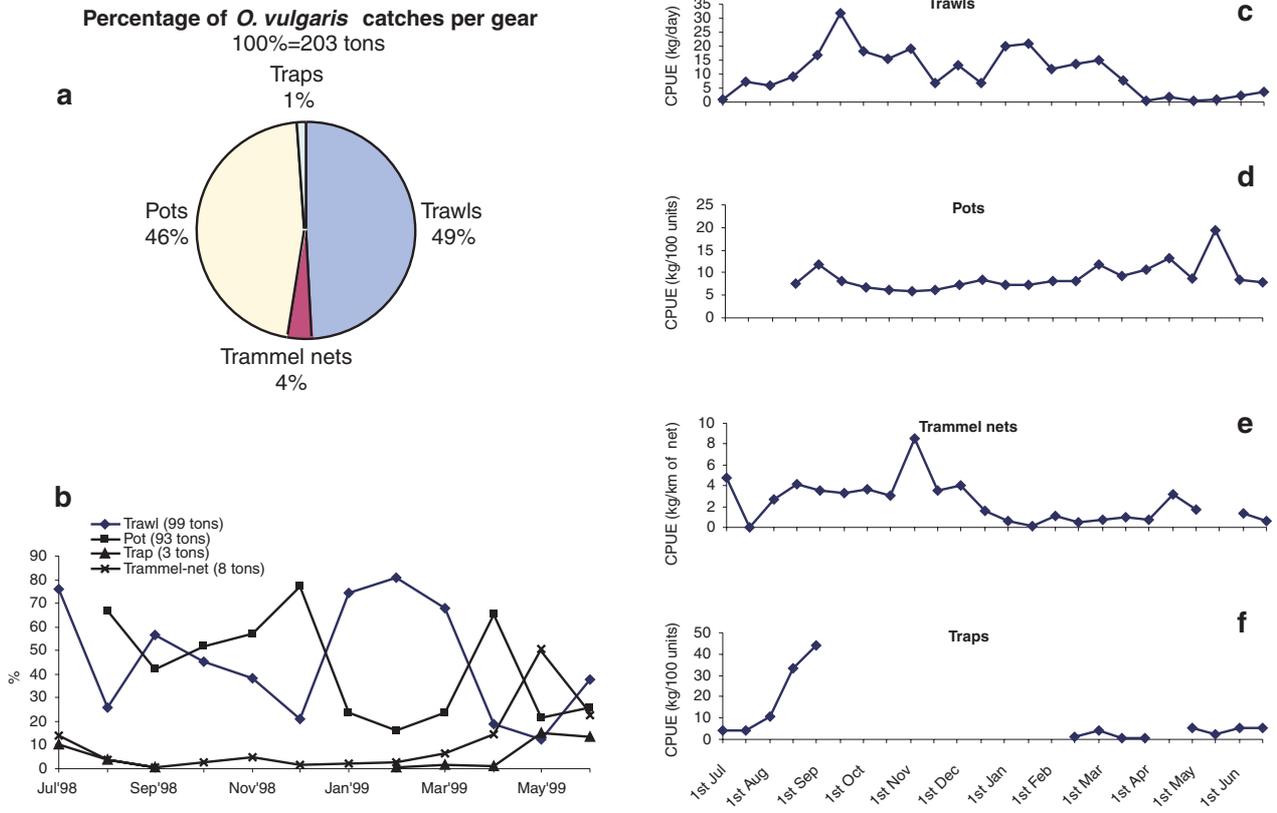


FIG. 3. – (a) Percentage of *O. vulgaris* catches per gear in the period studied; (b) Percentage of *O. vulgaris* monthly catches per gear; (c-f) CPUE of *O. vulgaris* by gear in the period studied. Fishery of Vilanova (Catalan Sea).

peak in the second half of September (31.7 kg/day) followed by a decline in the CPUE. In the case of the pots, the peak appears earlier, in the second half of May (19.4 kg /100 units). The CPUE of the traps is very irregular and the same is true of the trammel nets; however this gear catches *O. vulgaris* all the year.

Length distributions

In the fisheries of Kavala and Limenas, the range of sizes for trawls varies from 5.0 to 24.0 cm DML, while for beach-seines it is 5.0 to 19.0 cm DML and for fyke nets 7.0 to 23.0 cm DML (Fig. 4). The mean size for trawls is 11.0 cm DML, for beach seines 11.3 cm DML and for fyke nets 13.2 cm DML. The mean length frequency distributions by month indicate that large specimens appear in spring and small ones in autumn in the beach seines. This does not happen in trawls although the smallest individuals appear in November. The monthly progression of the mean size in fyke nets is comparatively more stable, since this gear is highly selective (Fig. 5).

Size frequencies by gear in the port of Vilanova are shown in Figure 6. Contrary to the Greek data, trawls catch higher quantities of small individuals

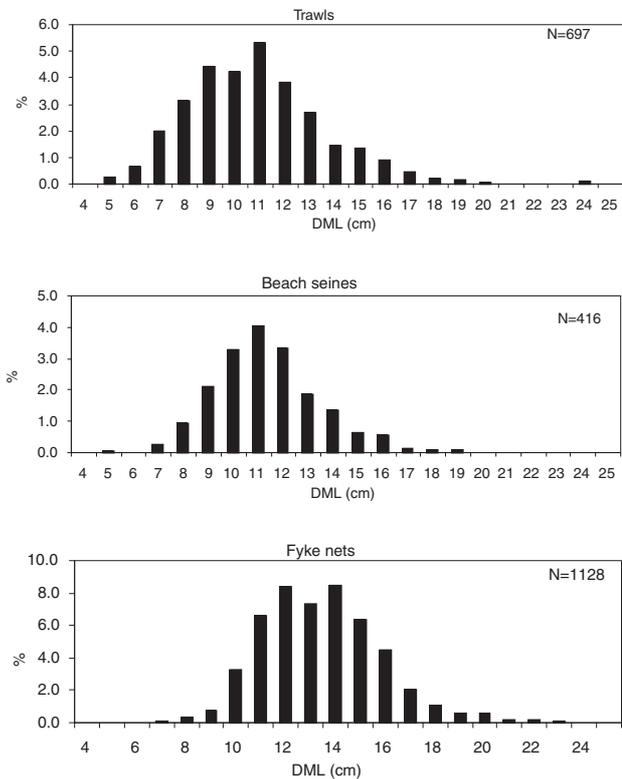


FIG. 4. – Length frequency distributions of *O. vulgaris* by gear in the fisheries of Kavala and Limenas (Thracian Sea).

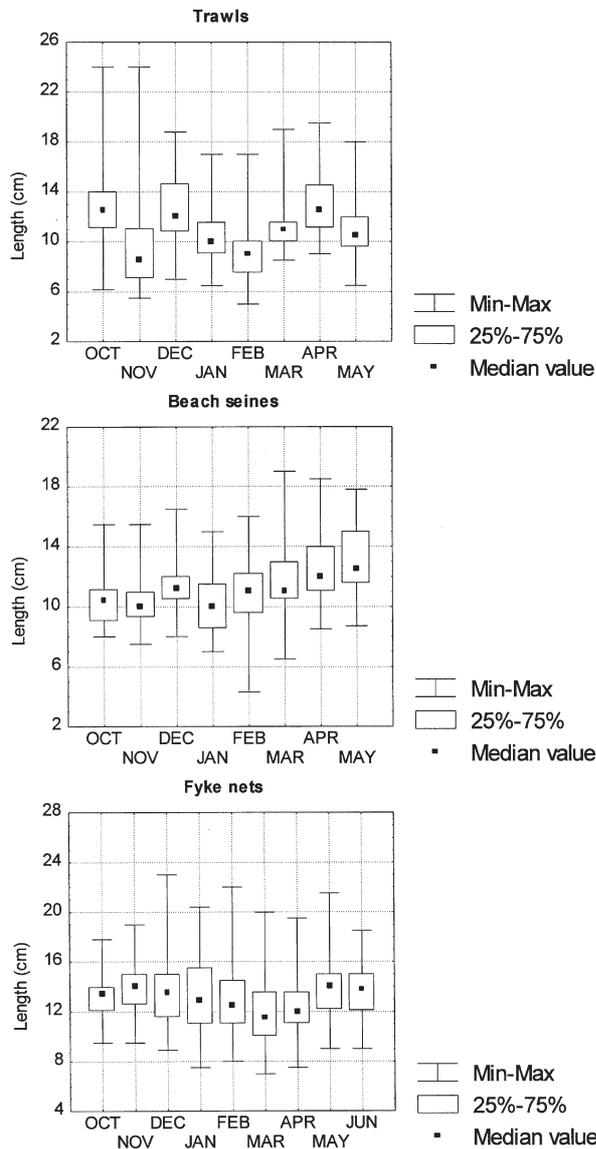


FIG. 5. – Mean length distributions of *O. vulgaris* by gear and month in the fisheries of Kavala and Limenas (Thracian Sea).

than the artisanal gears. The range of sizes in trawls varies from 10.0 to 32.0 cm DML, whereas for the pots it is from 9.0 to 32.0 cm DML. The size range for the trammel nets is from 9.0 to 35.0 cm DML and for traps it is 11.0 to 30.0 cm DML. The mean size for trawling is 14.7 cm DML. The mean size for the pots, on the other hand, is 18.8 cm DML and the mean size for the trammel nets is 19.9 cm DML. For the traps the mean size is 19.1 cm DML. The mean length frequency distributions by month show that the large specimens appear in spring and the small ones in autumn (Fig. 7).

It is clear that octopus in the Greek area studied are smaller (11.0-13.2 cm, mean DML) than in the Spanish area (14.7-19.9 cm, mean DML).

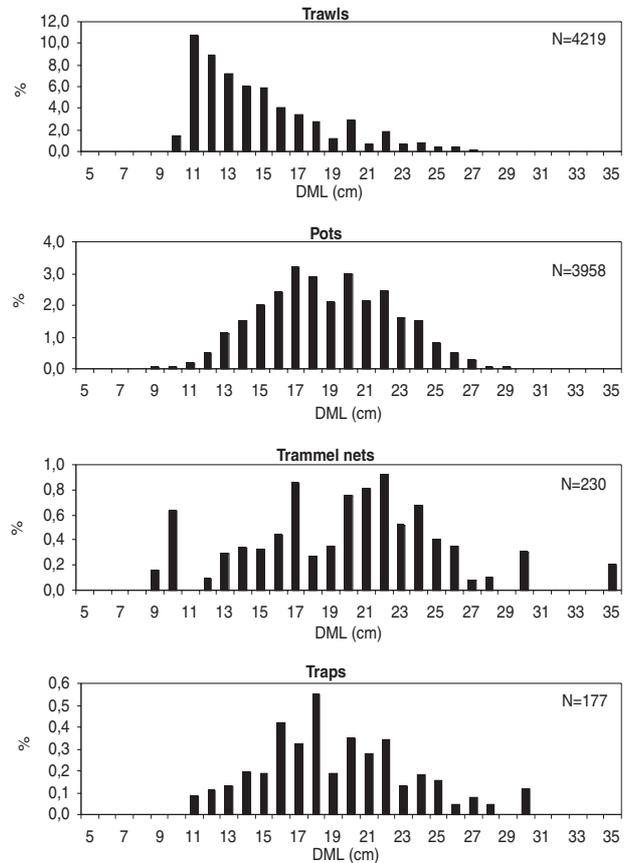


FIG. 6. – Length frequency distributions of *O. vulgaris* by gear in the fishery of Vilanova (Catalan Sea).

Interaction between the fishing gears

In the fisheries of Kavala and Limenas, the comparison between trawls and beach seines indicates an interaction in January, March and April. In the rest of the fishing period, the length data from the two gears are significantly different (Table 2). Trawl data differ significantly from those of fyke nets for most of the fishing period, excluding December and April. Finally, the comparison between beach seines and fyke nets shows that there is no interaction between the two gears from the beginning of the fishing period to February. An interaction of these two gears occurs in March, April and May.

In the fishery of Vilanova, the length range of *O. vulgaris* differs significantly between trawls and trammel nets in July, April, May and June (Table 2). Apart from July, trammel nets catch larger specimens than trawls. In August, November, January, February and March there are no significant differences between the two gears.

The comparison between the length range of the trawls' catch and of pots shows that the two gears have significant differences except in the months of

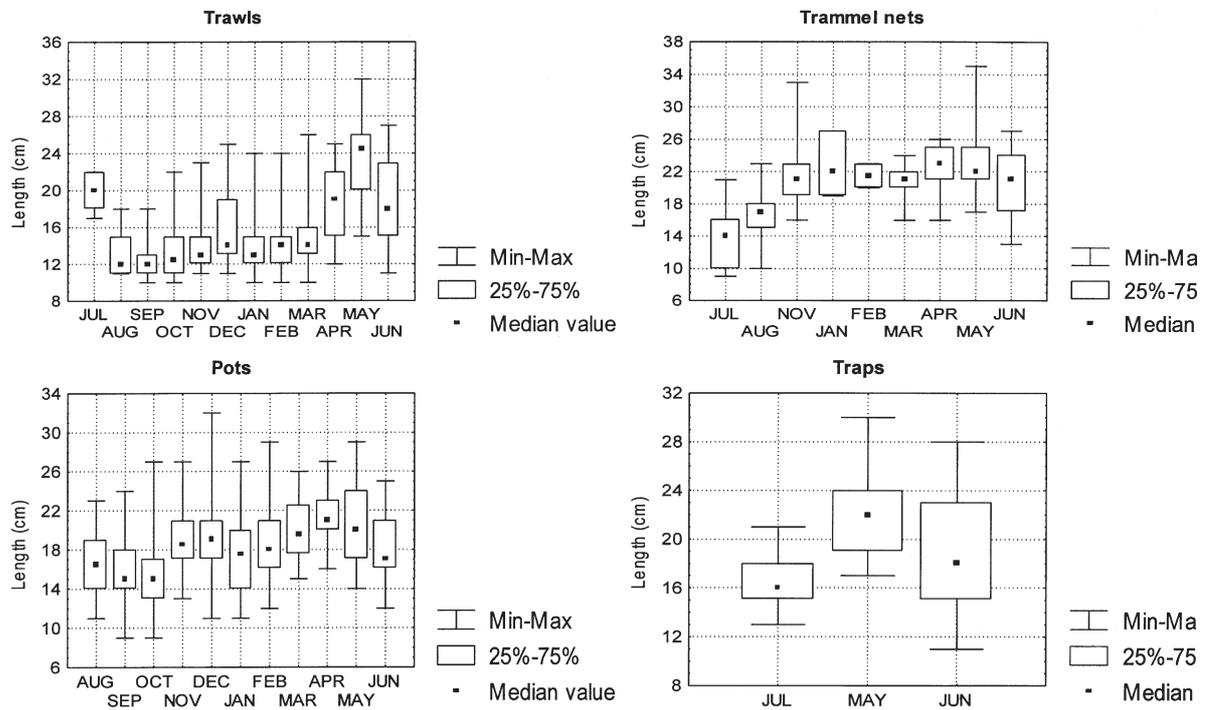


FIG. 7. – Mean length distributions of *O. vulgaris* by gear and month in the fishery of Vilanova (Catalan Sea).

August, January and February. In these months the length ranges caught by the two gears are very similar although their median values are different (Fig. 7).

Catches of *O. vulgaris* by traps are high in July, May and June. In July the length ranges of octopus differ significantly between trammel nets and traps while the trawls and traps show no significant differences in the range of length catches. In this month, trammel nets catch smaller animals than trawls or traps (Fig. 7). In May and June the four gears catch octopus and in all cases the length range is significantly different.

DISCUSSION

The common octopus, *O. vulgaris*, is a widely distributed species in the tropical, subtropical and temperate waters of the Atlantic, Indian and Pacific oceans and it has been known since remote antiquity when Aristotle correctly identified this species in the eastern Mediterranean (Mangold, 1983). It is abundant in the Mediterranean fisheries and constitutes an important fraction of the trawl catches (Sánchez and Martin, 1993; Sartor *et al.*, 1998; Quetglas *et al.*, 1998, Tsangridis *et al.*, 2000).

TABLE 2. – Interaction between the gears fishing *O. vulgaris* per month and area in the period studied (July 1998-June 1999).

GEARS	JUL'98	AUG'98	SEP'98	OCT'98	NOV'98	DEC'98	JAN'99	FEB'99	MAR'99	APR'99	MAY'99	JUN'99
Fisheries of Kavala and Limenas												
T-B				0.000*	0.001*	0.006*	0.254	0.000*	0.059	0.547	0.000*	
T-FN				0.005*	0.000*	0.423	0.000*	0.000*	0.009*	0.981	0.000*	
B-FN				0.000*	0.000*	0.000*	0.000*	0.000*	0.718	0.447	0.113	
Fishery of Vilanova												
T-TN	0.005*	1.000			1.000		0.368	1.000	0.406	0.001*	0.013*	0.000*
T-P		1.000	0.003*	0.000*	0.004*	0.000*	0.437	0.351	0.000*	0.000*	0.026	0.000*
T-TR	0.095										0.010*	0.000*
TN-P		0.043*			0.003*		0.368	0.317	0.104	0.000*	0.000*	0.000*
TN-TR	0.000*										0.000*	0.000*
P-TR											0.004*	0.000*

T: Trawls, B: Beach seines, TN: Trammel nets, FN: Fyke nets, P: Pots, TR: Traps
 *: Significant differences at probability level 0.05.

The biology of this species, which lives mostly in coastal waters, and its high commercial value in the Mediterranean since ancient times (Sartor *et al.*, 1998), have resulted in the development of specialised and highly productive artisanal gears (traps, pots, fyke nets) with which catches are practically monospecific. The landings of traps and pots at the Vilanova port make up 47% of the total octopus production, while at the port of Limenas fyke nets catch 30% of the total octopus production. It is worth mentioning that landings of trammel nets in the Kavala fishery are negligible while in the Vilanova fishery they reach 4% of the total octopus production. The significance of artisanal fishery in octopus production is also recorded on the Portuguese coasts, where it has accounted for an average of 79% of octopus landings in the last decade (Cunha and Moreno, 1994; Pereira, 1999).

Bottom trawling is, however, responsible for most octopus landings at both ports.

Trawl octopus catches in the port of Vilanova are lower than those in Kavala. This is perhaps a consequence of the more powerful trawl fleet in Kavala. We note that the CPUE values of trawls in the Kavala fishery are in most cases higher than those of Vilanova.

Catches show a marked seasonality, which is related to the short life span of the species, their rapid population turnover and their reproductive behaviour (Mangold, 1983; Boyle, 1990; Boyle and Boletzky, 1996). There is a phase difference in the highest catch rates obtained by trawls in the two areas studied. In the fishery of Kavala, the highest catch rates for trawls were obtained in winter and spring, while in the Vilanova fishery they were obtained in early autumn and winter. Quetglas *et al.* (1998), who studied the octopus trawl fishery in Mallorca (western Mediterranean) observed seasonality similar to that of the Kavala fishery. The cyclic behaviour of octopus landings is clear, as observed by Quetglas *et al.* (1998), but the seasonal pattern within a year seems to be variable depending on environmental and biological factors (Boyle and Boletzky, 1996). Marked seasonality of octopus catches has also been observed in trawl fisheries outside the Mediterranean. In the fisheries of Portugal and Venezuela the peak is recorded in late summer/autumn (Cunha and Moreno, 1994; Arocha, 1989), in Tokyo there are two peaks in summer and winter (Shimuzu, 1983), while in Gambia and Senegal there is a peak in summer (Anonymous, 1990).

Small-scale seasonal migrations and migratory schools of octopus occur in certain areas (Okutani, 1990; Anonymous, 1990). In the Kavala fishery, the reversed seasonality of octopus catches between beach seines and trawls provides an indication that octopuses migrate to the open sea in spring and return inshore in autumn. In this fishery, small sized individuals are present during the whole fishing period though they are more evident in November. This is an indication that in the eastern Mediterranean the reproductive period of the octopus is also irregular and long, as it is in the western Mediterranean, where it lasts from January to October with a maximum in April to July (Mangold and Boletzky, 1973; Guerra, 1975; Sánchez and Obarti, 1993; Quetglas *et al.*, 1998). An irregular reproductive pattern has also been observed in fisheries outside the Mediterranean Sea, in the Canary Islands (Hernández-García *et al.*, 1998), in the Azores Archipelago (Gonçalves, 1991) and in the Saharan Bank (quoted in Hernández-García *et al.*, 1998).

Considering that the maturity size of octopus as estimated by Sánchez and Obarti (1993) is 11-13 cm DML, we note that most of the trawl and beach seine landings at the port of Kavala consist of immature individuals. A large fraction of the trawl catches in the Vilanova fishery also consists of immature individuals. There are no length data from the past to determine whether there has been a reduction in the average size of octopus over time, as has been observed in the Saharan coasts (Hernández-García and Bas, 1993).

There is a certain overlapping in the size distributions of the different fishing gears exploiting octopus, particularly in April (Kavala fishery) and January-February (Vilanova fishery). However, in most cases there is little or no interaction between the gears fishing octopus, indicating that each gear affects a certain size range. Trawls generally catch the small sized individuals and artisanal fleets catch the large ones. This happens because octopuses live in coastal waters mainly between 0 and 50 m, occasionally reaching 200 m (Sánchez and Martín, 1993), and after spawning they die like the majority of cephalopod species. The artisanal gears (pots, traps, trammel nets, beach seines and fyke nets) usually work in shallow waters (<50m) and it is here that most of the adult individuals are caught. Consequently, only a part of the population (mostly immature) is available to the trawl fishery. Thus, there is no overlapping of the fishing grounds for the different types of gears exploiting octopus.

It is worth noting that individuals from the Kavala and Limenas fisheries are clearly smaller than the ones from Vilanova. Recent developments in the study of octopus populations using molecular markers suggest that there is a degree of genetic divergence between the eastern and western Mediterranean octopus populations (Murphy *et al.*, 2000; Maltagliati *et al.*, 2000). Further research on genetics and biometrics is needed to examine the likely occurrence of the eastern nanism hypothesis suggested first by Pérès and Picard (1958) for benthic invertebrates.

In summary, it seems that in both areas studied, trawls as compared to the artisanal fleets, exploit smaller specimens and mostly the individuals that have not yet reached maturity. On the other hand, artisans mainly exploit the spawners. This may be a risky situation for the octopus populations in the Mediterranean, especially if we consider that we are dealing with multispecies and multigear fisheries in which fishing regulations for most of the artisanal gears are either scarce or inadequate. This situation provides further evidence for the view that being optimistic for the future of the Mediterranean fisheries is dangerous, or at least contrary to the precautionary principle (cf. Leonart, 1997).

Therefore, it is obvious that immediate action is certainly needed by turning to more effective management strategies, particularly in coastal waters (Sherman and Duda, 1999). The creation of marine harvest refuges (cf. Stergiou *et al.*, 1997; Pauly *et al.*, 1998) may prove beneficial for the conservation of octopus populations and the viability of the complex fisheries of this species.

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