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Fisheries Resources in the Deep Waters of the Eastern Mediterranean (Greek Ionian Sea)

C.-Y. Politou, S. Kavadas and Ch. Mytilineou
National Centre for Marine Research, Ag. Kosmas, 16604 Helliniko, Athens, Greece

A. Tursi and R. Carlucci
Department of Zoology, University of Bari, Via Orabona 4, I-70125 Bari, Italy

G. Lembo
COISPA, Tecnologia e Ricerca, Mola di Bari, C.P. 62, Italy

Abstract

The deep waters of the Greek seas are unexploited, since trawling is carried out mainly down to 400 m. In the present work, the fisheries resources of the deep waters (300–900 m) of the Greek Ionian Sea were studied in spring, summer and autumn 2000 by means of experimental trawl surveys. The results showed that in the zone 300–500 m, fish composed 73–83% by number or 89–92% by weight of the catch depending on the season, crustaceans 16–25% by number or 6% by weight and cephalopods 1–2% by number or 3–5% by weight. In the zone 500–700 m, crustaceans composed 28–41% by numbers or 67–80% by weight of the catch, whereas the proportion of cephalopods was less than 1% by number and about 1% by weight. In the deepest zone (700–900 m), the proportion of cephalopods remained negligible, whereas the proportion of fish increased and was about equal in numbers with that of crustaceans, whereas in weight it ranged from 81 to 86%. The CPUE of commercial fish was 23–59 kg/hr in the first depth stratum, 7–25 kg/hr in the second one and 2–10 kg/hr in the third one, depending on the season. Concerning the commercial crustaceans, their CPUE was 3–6.5 kg/hr in the shallowest zone, 6–8.5 kg/hr in the middle one and 2–4 kg/hr in the deepest one. The commercial part of cephalopod catch ranged from 1 to 7 kg/hr in the zone 300-500 m, whereas deeper it was negligible. Commercial/total ratio by weight of the whole catch was highest in the 500–700 m zone (0.60–0.78), whereas in the other zones it was generally lower than 0.50.

Key words: fisheries resources, deep water, Mediterranean Sea, seasonality

Introduction

The overexploitation of the continental shelves in most of the world has led to an increasing interest in deep-water fisheries. Deep-water trawl fisheries and generally large-scale modern fisheries based on deep-sea species began in the 1970s in different areas of the world such as in the west of Scotland and Ireland and in Australia and New Zealand (Gordon, 2001; Haedrich *et al*., 2001).

In the Mediterranean, deep waters are exploited by trawl in its western and central part. Trawl fishing, targeting mainly red shrimps, is carried out in Mediterranean Spanish waters and Italian waters down to 800-1 000 m of depth (Sardà and Cartes, 1994; Carbonell, 1994; Righini and Abella, 1994). In parallel, knowledge on the deep-water fisheries resources of this part of the Mediterranean comes from scientific research, which has recently been expanded also to depths greater than 800–1 000 m (e.g. Abella *et al*., 1988; Cartes and Sardà, 1992, 1993; Cartes, 1993; Cartes *et al*., 1994; D'Onghia *et al*., 1998; Stefanescu *et al*., 1992a, b, 1993, 1994; Ungaro *et al*., 1999).

In the Greek waters, the commercial fishery is carried out mainly down to a depth of 400 m. The geomorphology of the Greek continental margin, and particularly that of the Ionian Sea, is characterized by steep bottoms and narrow continental shelf. As a result, large marine grounds remain unexploited, while the stocks of a narrow area along the coast suffer from overexploitation (Stergiou *et al*., 1997).

With little or no deep water fishing in the Greek seas, scientists have been given the opportunity to study the natural environment in order to determine the distribution and abundance of local populations, study their biology and dynamics and plan a reasonable management design. This kind of research started recently in the framework of larger projects (MEDITS projects 1994-2001) or in restricted areas of the Ionian Sea (Anon., 1999; Anon., 2001) and Cretan Sea (Kallianiotis *et al*., 2000). The present study is carried out in an extended area of the Ionian Sea in the framework of the project INTERREG Italy-Greece. In this paper, the results concerning the fisheries resources of the deep waters of the Greek Ionian Sea for different depth strata and seasons are presented.

Materials and Methods

Sampling took place at depths from 300 to 900 m in the Greek Ionian Sea during spring, summer and autumn 2000 (Fig. 1) using a chartered commercial trawler. The size of the fishing vessel was 33.1 m maximum length and 8 m maximum width, and its engine power was 730 HP. The gear used was an Italian type bottom trawl with a cod end mesh size of 20 mm (side). The horizontal and vertical opening of the trawl were estimated, using a remote acoustic sensing system attached to the gear, as 1.5 m and 17 m respectively at a towing speed of 2.4 knots. The random stratified sampling design was applied using depth for the stratification of the study area. Three depth zones were defined, 300–500 m, 500–700 m and 700–900 m. A total of 107 hauls were carried out (Table 1). The tow duration was 30 minutes for depths <500 m and one hour for depths >500 m. After each haul, catches were identified to species level. Species abundance in number and weight were recorded on board. The catch per unit effort (CPUE) in weight per fishing hour was estimated as follows for each depth zone:

$$\text{CPUE} = \Sigma W_n / \Sigma t_n$$

where ΣW_n = sum of weights of a species or category in the n hauls carried out in the depth zone and Σt_n = sum of fishing time of the n hauls in the depth zone. The Mann-Whitney non parametric test was used to check if there were statistically significant differences in CPUE in relation to depth or to season (p<0.05). Consequently, the commercial/total (C/T) ratio was calculated for each fishing category and for the total catch. The separation between commercial and non-commercial species is shown in Table 2.

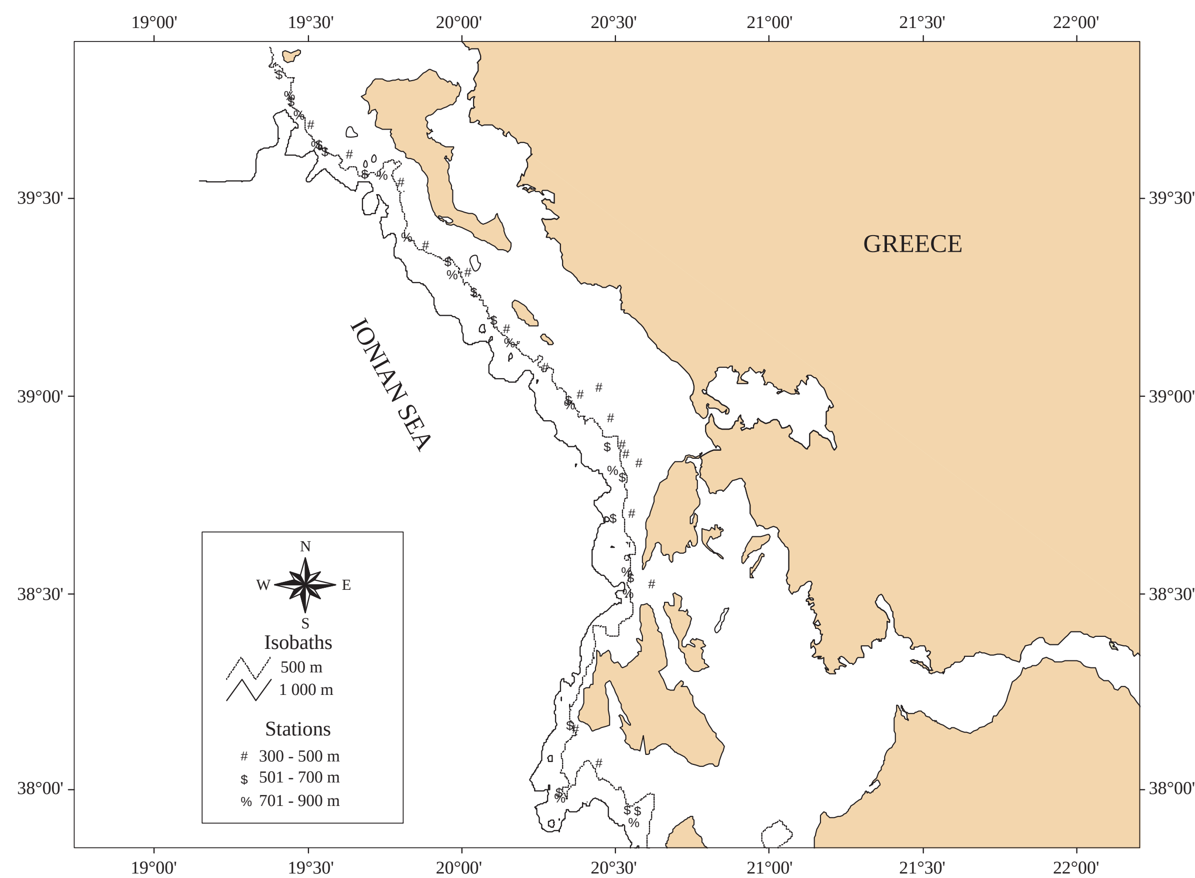

Fig. 1. Map of the study area showing the sampling stations.

TABLE 1. Number of hauls carried out in the Ionian Sea per season and depth stratum.

	Season/depth stratum		
	300–500 m	500–700 m	700–900 m
Spring	17	17	13
Summer	6	15	11
Autumn	3	14	11

TABLE 2. List of species caught with CPUE (kg/hr) per depth stratum and season. In bold are shown the commercial or possibly commercial species.

	300–500 m			500–700 m			700–900 m		
Species	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
				FISH					
Argentina sphyraena	2.99	5.83	2.55	0.01	0.04	0.03			0.04
Arnoglossus rueppelli	0.15	0.10	0.01						
Aspitrigla cuculus	**0.32**	**0.28**							
Capros aper	0.60	4.25	0.11						
Centracanthus cirrus	**0.03**								
Centrolophus niger						0.41			0.78
Centrophorus granulosus				**0.19**		**2.34**	**0.41**	**0.73**	
Chauliodus sloani		0.03		0.01	0.01		0.01	0.03	0.01
Chimaera monstrosa				0.07			0.15	0.11	
Chlorophthalmus agassizii	25.50	42.28	47.70	1.55	3.91	1.14		0.04	0.25
Coelorhynchus coelorhynchus	0.96	1.47	1.16	0.08	0.24	0.16		0.01	0.03
Conger conger	**0.11**	**0.10**	**0.45**	**0.21**		**0.09**	**0.43**	**0.02**	**0.43**
Dalatias licha				0.04	0.02		0.62	1.04	0.49
Deltentosteus quadrimaculatus		0.01							
Diaphus metopoclampus						0.01			
Epigonus constanciae					0.02				
Epigonus telescopus	0.05				0.04			0.17	
Etmopterus spinax	0.02			0.11	0.30	0.12	0.12	0.26	0.34
Eutrigla gurnardus			**0.03**						
Gadella maraldi							0.02		
Gadiculus argenteus argenteus	1.11	4.53	12.41						
Galeus melastomus	**1.42**	**3.46**	**4.14**	**2.93**	**5.69**	**4.16**	**4.37**	**8.67**	**4.62**
Gnathophis mystax							0.03		
Helicolenus dactylopterus	**2.06**	**1.03**	**0.38**	**4.13**	**7.90**	**7.13**	**1.39**	**2.54**	**1.79**
Heptranchias perlo		0.53							
Hexanchus griseus									1.33
Hoplostethus mediterraneus		0.13		1.00	3.74	1.84	0.75	1.81	0.87
Hymenocephalus italicus	0.55	3.41	2.00	0.19	0.34	0.21	0.01	0.02	0.03
Lampanyctus crocodilus		0.03		0.11	0.19	0.08	0.17	0.29	0.17
Lepidopus caudatus	**0.01**	**0.22**		**0.04**	**0.02**	**0.12**			
Lepidorhombus boscii	**2.04**	**3.40**	**6.75**	**0.13**	**1.01**	**1.20**			**0.11**
Lepidorhombus whiffiagonis	**1.24**	**0.79**	**0.75**		**0.27**	**0.65**			**0.11**
Lepidotrigla dieuzeidei	0.81	0.82	0.19		0.01				
Lophius budegassa	**1.16**	**2.23**	**1.24**	**0.42**	**0.48**	**0.24**		**1.82**	**0.02**
Lophius piscatorius	**2.19**				**3.36**	**3.60**		**4.32**	
Maurolicus muelleri		0.04							
Merluccius merluccius	**1.45**	**6.21**	**9.23**	**0.18**	**0.53**	**2.02**	**0.03**	**0.10**	**0.43**
Micromesistius poutassou poutassou	**0.39**	**1.44**	**17.29**	**0.18**	**0.18**	**0.33**			
Molva dipterygia macrophthalma	0.08	0.23		0.04	0.26	0.11		0.10	0.04

TABLE 2. (Continued). List of species caught with CPUE (kg/hr) per depth stratum and season. In bold are shown the commercial or possibly commercial species.

Species	300–500 m			500–700 m			700–900 m		
	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
FISH (Continued)									
Mora moro				0.03	0.09	0.10	1.75	2.96	1.44
Mullus barbatus	**0.01**								
Mullus surmuletus	**0.60**								
Mustelus mustelus					**0.80**				
Nettastoma melanurum	0.02	0.08	0.13	0.11	0.27	0.12	0.41	0.59	0.42
Nezumia sclerorhynchus		0.03		0.28	0.50	0.54	0.38	0.58	0.37
Notacanthus bonapartei							0.01		
Oxynotus centrina						0.38		0.01	0.03
Pagellus acarne	**0.47**	**0.05**							
Pagellus bogaraveo	**0.55**	**1.42**	**3.75**	**0.34**	**0.56**	**0.11**			**0.15**
Peristedion cataphractum	1.79	3.28	0.90	0.13	0.07	0.07	0.01		0.03
Phycis blennoides	**0.91**	**1.68**	**2.19**	**0.63**	**1.38**	**2.23**	**0.14**	**0.99**	**0.50**
Polyprion americanus						**0.28**	**0.16**		
Raja asterias		0.14	0.32						
Raja clavata	**1.26**	**0.50**	**1.47**						
Raja miraletus			0.75						
Raja montagui	**0.15**	**0.55**							
Raja oxyrinchus	3.01	2.11	0.60	0.03	0.16	0.21			
Raja polystigma	0.03								
Scorpaena elongata	**0.55**	**0.38**		**0.04**					
Scyliorhinus canicula	**1.33**	**1.78**	**6.02**	**0.03**			**0.01**		**0.03**
Spicara smaris	**0.01**								
Squalus blainvillei	**6.70**	**3.02**	**10.28**	**0.04**	**0.13**	**4.97**	**0.01**	**0.56**	**0.29**
Stomias boa		0.01		0.01	0.04	0.01		0.03	0.01
Synchiropus phaeton	0.02	0.03			0.01				
Torpedo marmorata	0.03								
Torpedo nobiliana	0.37								
Trachurus picturatus	**0.13**								
Trachurus trachurus	**0.24**	**0.18**							
Trachyrhynchus trachyrhynchus	0.02						0.16	0.17	0.17
Trigla lucerna		**0.22**							
Trigla lyra	**0.66**	**0.30**	**0.30**	**0.02**	**0.01**	**0.07**			
Trisopterus minutus capelanus		**0.02**							
Zeus faber	**0.02**								
CRUSTACEANS									
Aegaeon lacazei			0.01						
Aristaeomorpha foliacea		**0.01**		**4.29**	**5.71**	**5.84**	**1.79**	**2.81**	**1.23**
Aristeus antennatus				**0.53**	**0.65**	**0.39**	**0.74**	**1.07**	**0.29**
Bathynectes longipes						0.01			
Bathynectes maravigna		0.01			0.01				
Calappa granulata	**0.04**								
Chlorotocus gracicornis		0.01							
Geryon longipes							0.01		
Macropipus tuberculatus			0.01						
Munida iris	0.07	0.01							
Munida perarmata									
Nephrops norvegicus	**0.19**	**0.40**	**0.41**	**0.17**	**0.21**	**0.07**		**0.01**	**0.05**
Parapenaeus longirostris	**2.44**	**4.69**	**6.13**	**0.03**	**0.18**	**0.07**		**0.01**	**0.01**
Paromola cuvieri					0.05	0.02		0.03	0.04

TABLE 2. (Continued). List of species caught with CPUE (kg/hr) per depth stratum and season. In bold are shown the commercial or possibly commercial species.

Species	300–500 m			500–700 m			700–900 m		
	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
CRUSTACEANS (Continued)									
Parthenope macrochelos	0.01								
Pasiphaea multidentata								0.01	0.01
Pasiphaea sivado				0.01	0.25	0.01			
Plesionika acanthonotus	0.01			0.04	0.01	0.01			
Plesionika antigai	0.16	0.10	0.04		0.01				
Plesionika edwardsii	**0.52**	**0.07**		**0.04**	**0.05**	**0.07**			**0.83**
Plesionika gigliolii	0.03	0.08	0.04	0.02	0.01				
Plesionika heterocarpus	**0.30**	**0.97**	**2.81**		**0.01**				
Plesionika martia	**0.12**			**1.32**	**1.79**	**1.57**	**0.01**	**0.04**	**0.02**
Polycheles typhlops				0.06	0.06	0.07	0.04	0.04	0.03
Sergestes robustus							0.01	0.01	0.01
CEPHALOPODS									
Alloteuthis media		0.01	0.01						
Ancistroteuthis lichtensteini	0.01	0.01							
Eledone cirrhosa	**0.01**	**0.02**	**0.10**						
Illex coindetii	**0.13**		**1.13**			**0.05**			
Loligo forbesi	**0.51**	**1.57**	**2.05**		**0.06**	**0.12**			
Neorossia caroli				0.05	0.05	0.04		0.02	
Octopus salutii	0.01		0.03						
Octopus vulgaris						**0.03**			
Pteroctopus tetracirrhus	0.47	0.85	0.01	0.13	0.03	0.02	0.04		
Rondeletiola minor	0.02	0.03	0.03						
Rossia macrosoma	0.05	0.11	0.24			0.02			
Scaeurgus unicirrhus	0.04	0.02	0.03				0.03		
Sepia elegans	0.03	0.07							
Sepia orbignyana	**0.09**	**0.05**	**0.05**						
Sepietta oweniana	0.13	0.21	0.51						
Sepiola ligulata		0.02							
Todarodes sagittatus		**0.58**	**3.30**		**0.16**	**0.34**		**0.05**	**0.02**
Todaropsis eblanae	**0.49**	**0.05**	**0.21**				**0.01**		

Results

Catch composition

Fish was the main component of the catch by weight independently of depth and season, whereas in terms of numbers, fish dominated in the catch only in the first stratum (Fig. 2). Crustaceans ranked second, after fish, in weight in all cases. However, in terms of numbers crustaceans were dominant in the 500–700 m depth zone during all seasons and almost equal to fish in the deepest zone. Finally, cephalopods always composed a low proportion of the catch (0.1–5.1% by weight and 0.2–2% by number) being more important in the first stratum (300–500 m).

A list of species of each category caught per depth stratum and season is given in Table 2.

CPUE

The total CPUE ranged from 14 kg/hr to 150 kg/hr depending on the depth stratum and the season (Table 3). CPUE varied with depth, during all seasons, it was highest in the first stratum (300–500 m), and it decreased gradually reaching its minimum in the deepest stratum (700–900 m). With respect to seasonality CPUE was lowest at all depths during spring, although in the deepest stratum, the seasonal difference was not statistically significant (Table 3). A similar bathymetric and seasonal pattern was followed by the

TABLE 3. CPUE (Kg/hr) of the total, commercial (CO) and non-commercial (NC) catch per depth zone and season. The ratio of the commercial to the total catch (C/T) is also presented. (In parentheses is given the standard deviation. [1,…,7] indicate homogenous groups for the total catch, [a,…,e] indicate homogenous groups for the commercial catch and [I,…,VIII] indicate homogenous groups for the non-commercial catch, Mann-Whitney test, $P<0.05$).

Season		Depth zone 300–500 m	500–700 m	700–900 m
	CO	27.28[b]	12.99	4.98[e]
		(16.87)	(7.08)	(4.41)
Spring	NC	42.70[IV,V]	7.08[I,VI]	9.25[I, VIII]
		(35.74)	(6.72)	(5.86)
	Total	69.98[4]	20.07[1]	14.23[1,7]
		(42.40)	(10.14)	(9.39)
	C/T	0.39	0.65	0.35
	CO	31.87[a,b,c]	25.72[a,d]	14.34[a,c,e]
		(20.68)	(23.14)	(12.90)
Summer	NC	77.15[IV]	16.86[II, VII]	17.63[II,VIII]
		64.65)	(10.44)	(9.66)
	Total	109.02[2,4,5]	42.58[2,3,6]	31.97[3,7]
		(78.27)	(28.64)	(20.81)
	C/T	0.29	0.60	0.45
	CO	71.97[c]	33.81[d]	7.06[e]
		(15.00)	(21.11)	(2.41)
Autumn	NC	78.32[V]	9.52[III,VI,VII]	10.80[III,VIII]
		(46.36)	(4.31)	(4.82)
	Total	150.29[5]	43.33[6]	17.86[7]
		(61.36)	(22.12)	(5.70)
	C/T	0.48	0.78	0.40

commercial part of the catch, which ranged from 72 kg/hr to 5 kg/hr, even though the bathymetric differences during summer were not statistically significant.

The commercial/total (C/T) ratio by weight of the whole catch attained the highest values in the stratum 500–700 m (0.60–0.78). In the other zones, it was generally lower than 0.50, and it ranged from 0.29 to 0.48 in the zone 300–500 m and from 0.35 to 0.45 in the zone 700–900 m.

a) **Fish**

The CPUE of fish ranged from 11.5 kg/hr (700–900 m, spring) to 133 kg/hr (300–500 m, autumn), and its variation with depth and season followed the same pattern with that of the total CPUE (Fig. 3).

In the shallower zone, the ratio C/T for fish was generally low (0.25–0.44), and the commercial part of the fish catch showed a CPUE ranging from 23 kg/hr (spring) to 59 kg/hr (autumn). A total of 60 fish species were caught in this zone. The most important of these, caught constantly in high quantities was *Chlorophthalmus agassizii* (25.5–47.7 kg/hr) (Table 2). Another important species was *Squalus blainvillei* (3-10.3 kg/hr). *Merluccius merluccius* and *Galeus melastomus* were constantly present in the shallowest depth zone with CPUE ranging from 1.5 kg/hr (spring) to 9.2 kg/hr (autumn) and from 1.4 kg/hr (spring) to 4.1 kg/hr (autumn), respectively. *Gadiculus argenteus* and *Scyliorhinus canicula* were also found constantly in this stratum with a peak of 12.4 kg/hr and 6 kg/hr, respectively, in autumn. The CPUE of *Argentina sphyraena* was also important (2.6–5.8 kg/h). *Micromesistius poutassou* showed a high CPUE in autumn (17.3 kg/hr). Finally, the CPUE of *Lepidorhombus boscii* ranged from 2 kg/hr (spring) to 6.8 kg/hr (autumn).

The stratum 500–700 m showed the highest C/T ratios for fish (0.49–0.73), and the CPUE of commer-

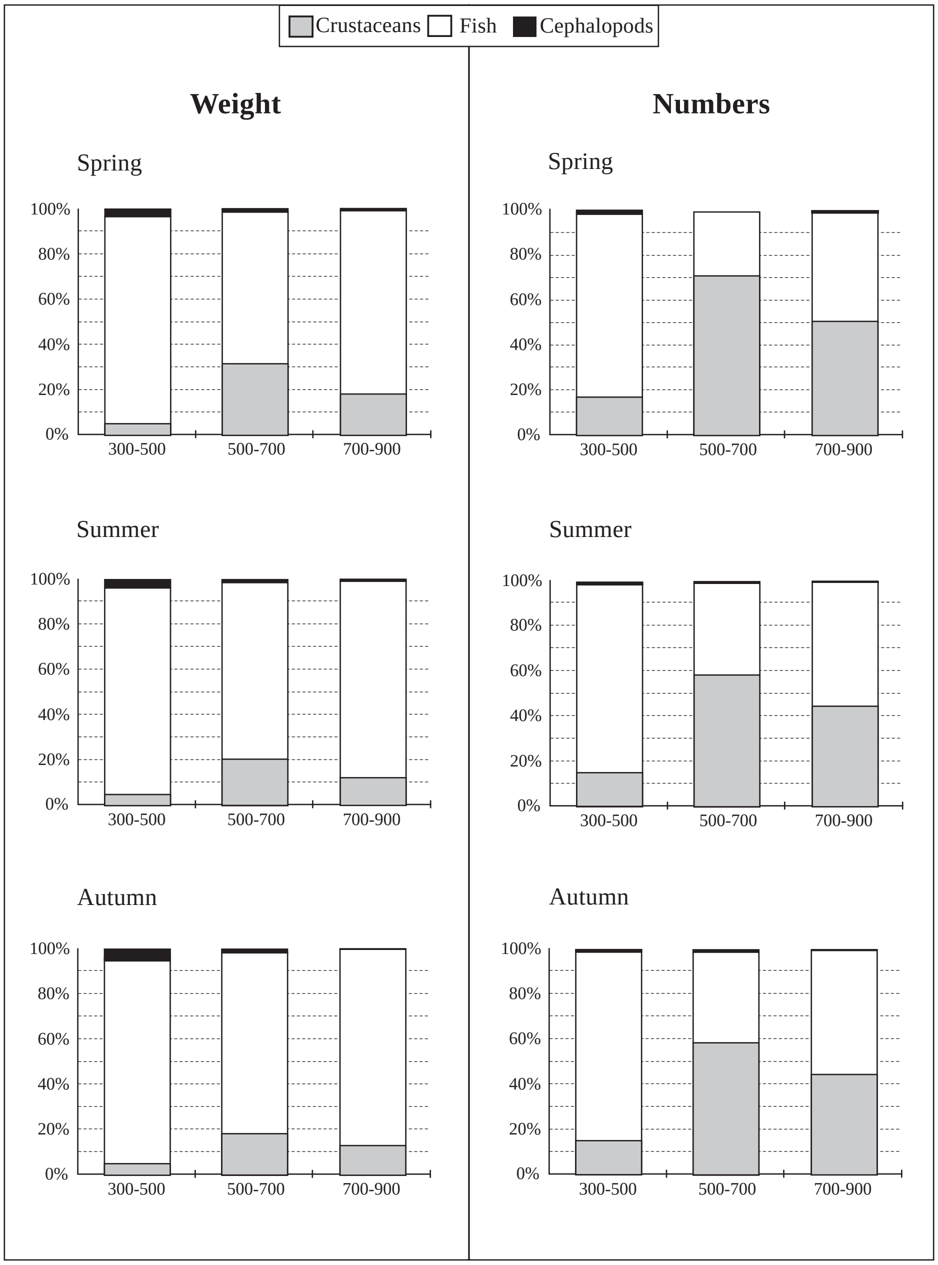

Fig. 2. Catch composition as proportion (%) by weight (kg/hr) and by number (N/hr) per depth stratum and season.

cial fish ranged from 7 kg/hr (spring) to 25 kg/hr (autumn). The most important of the 43 fish species of this zone were *Helicolenus dactylopterus* with CPUE ranging from 4.1 kg/hr (spring) to 7.9 kg/hr (summer) and *G. melastomus* with CPUE ranging from 2.9 kg/hr (spring) to 5.7 kg/hr (summer). *Hoplostethus mediterraneus* and *C. agassizii* were also found constantly with CPUE ranging from 1 to 3.7 kg/hr and from 1.1 to 3.9 kg/hr, respectively. *Phycis blennoides* was found in this zone with CPUE ranging between 0.6 kg/hr and 2.2 kg/hr. Other notable species included *Lophius piscatorius* found in summer and autumn (3.4–3.6 kg/hr), *S. blainvillei* with maximum CPUE during autumn (5 kg/hr) and *M. merluccius* with maximum CPUE also in autumn (2 kg/hr).

In the zone 700–900 m, the C/T ratio of fish was low (0.21–0.37) with the CPUE of the commercial

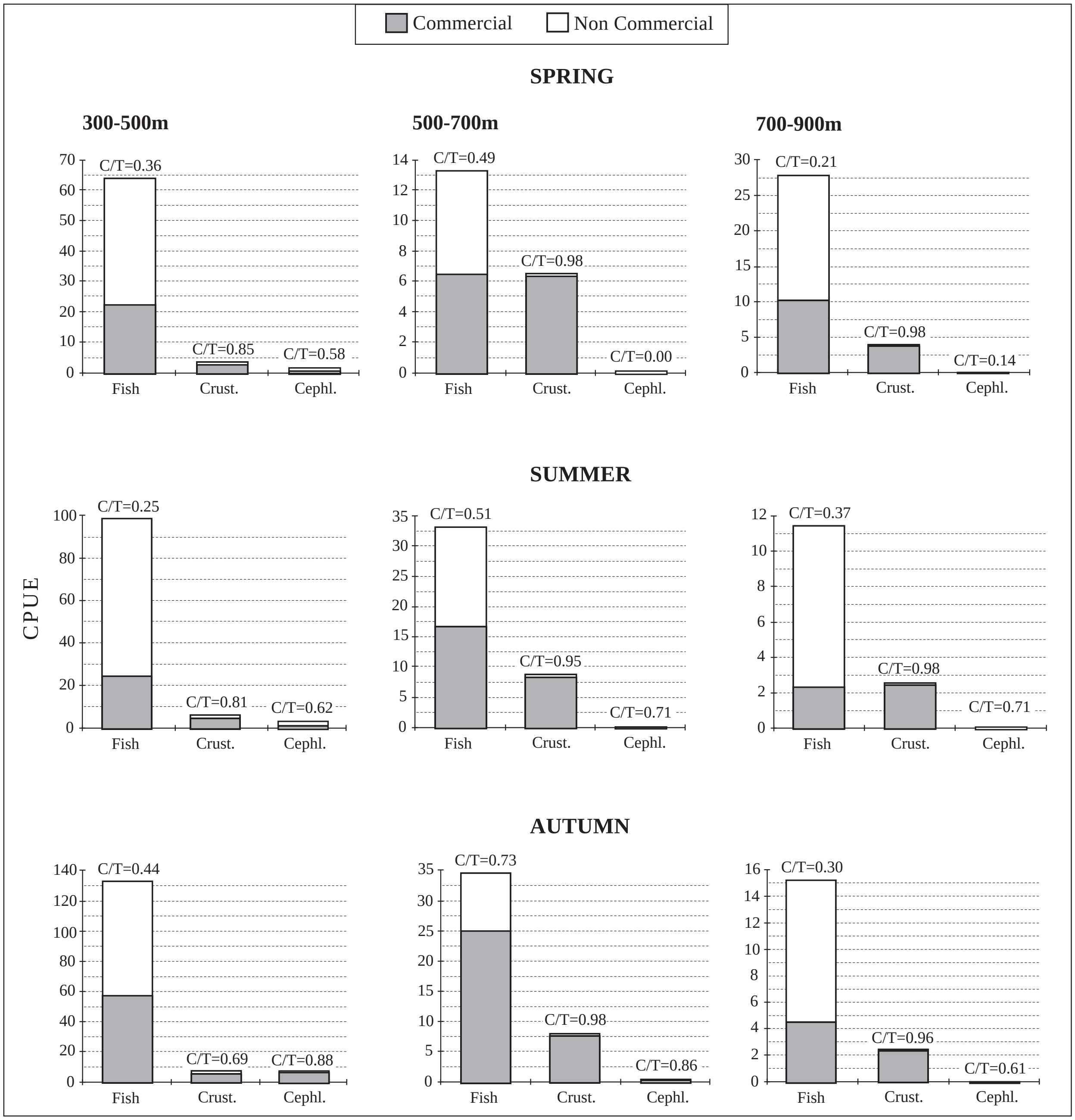

Fig. 3. CPUE (kg/hr) of the total, commercial and non-commercial fish, crustacean and cephalopod catch per depth zone and season. The ratio of the commercial to the total catch (C/T) is also presented.

part ranging from 2 kg/hr (spring) to 10 kg/hr (summer). A total of 37 fish species were found in this depth zone. *G. melastomus* was dominant (4.4–8.7 kg/hr) with *Mora moro* (1.4–3 kg/hr) and *H. dactylopterus* (1.4–2.5 kg/hr) following. *H. mediterraneus* was caught in lower quantities (0.8–1.8 kg/hr), whereas *L. piscatorius* and *L. budegassa* were found in relatively high quantities in summer (4.3 and 1.8 kg/hr, respectively).

b) **Crustaceans**

The CPUE of crustaceans ranged from 2.5 kg/hr (700–900 m, autumn) to 9.5 kg/hr (300–500 m, autumn) (Fig. 3). It took its highest values in the middle stratum (spring, summer) or the first stratum (autumn) and the lowest ones in the deepest stratum during all seasons. The C/T ratio was always high (0.69-0.98).

In the shallower stratum, the C/T ratio of crustaceans showed lower values (0.69–0.85) compared to the deeper zones, and the CPUE of the commercial catch ranged from 3 kg/hr (spring) to 6.5 kg/hr (autumn). A total of 16 crustacean species were found in this depth zone, and *Parapenaeus longirostris* was the dominant species during all seasons (2.4–6.1 kg/hr). *Plesionika heterocarpus* also had a constant presence in the catch of this depth zone with a CPUE of 2.8 kg/hr in autumn.

The middle zone displayed the maximum CPUE of commercial crustaceans (6-8.5 kg/hr) with C/T always higher than 0.9. From the 15 species caught, *Aristaeomorpha foliacea* (4.3–5.8 kg/hr) followed by *Plesionika martia* (1.3–1.8 kg/hr) were the most important species. *Aristeus antennatus* was also found constantly in low quantities (0.4–0.65 kg/hr).

In the deeper zone, a decrease in the catch of crustaceans was observed and although the C/T ratio remained high (>0.95), the CPUE of the commercial part ranged between 2 and 4 kg/h. From the 11 species found in that zone, *A. foliacea* (1.2–2.8 kg/hr) was the main species caught with *A. antennatus* (0.3–1.1 kg/hr) ranking second.

c) **Cephalopods**

The total CPUE of cephalopods ranged from 0.03 kg/hr (700–900 m, autumn) to 7.7 kg/hr (300–500 m, autumn) and it showed an important decrease with depth during all the surveys (Fig. 3).

In the first stratum, the C/T ratio was high (0.58–0.88) and the commercial cephalopod catch had a CPUE range from 1 kg/hr (spring) to 7 kg/hr (autumn). A total of 16 cephalopod species were caught in this zone. From these, *Loligo forbesi* was the most important species found during all seasons with CPUE ranging from 0.5 kg/hr (spring) to 2.1 kg/hr (autumn). *Todarodes sagittatus* was found in relatively high quantities in autumn (3.3 kg/hr). *Illex coindetii* was also important in autumn (1.1 kg/hr). Finally, *Pteroctopus tetracirrhus* was present in low quantities (<1 kg/hr) in all surveys, but during autumn its CPUE was negligible.

In the second stratum, the CPUE of cephalopods ranged from to 0.2 kg/hr (spring) to 0.6 kg/hr (autumn). From the 7 species caught, the most notable species was *Todarodes sagittatus,* which contributed in the catch in autumn and summer with low CPUE (<1 kg/hr).

In the third stratum, the CPUE of cephalopods was always lower than 0.1 kg/h. 5 species were found in that depth stratum.

Discussion

The prevailing role of depth, with a secondary seasonal influence, on the demersal fish and megafaunal changes in the Greek waters and more generally in the Mediterranean has already been documented by different authors (Abelló *et al*., 1988; Cartes and Sardà, 1992, 1993; Cartes, 1993; Cartes *et al*., 1994; D'Onghia *et al*., 1998, Stefanescu *et al*., 1994; Ungaro *et al*., 1999; Kallianiotis *et al*., 2000; Labropoulou and Papaconstantinou, 2000a). Our results showed a general pattern where fish were highly dominant (in number and weight) in depths 300–500 m with crustaceans and cephalopods ranking second and third, respectively, independent of season. The importance of crustaceans increased in increasing depths (500–900 m) and mainly in the zone 500–700 m, although fish remained dominant in terms of weight. On the contrary, the presence of cephalopods was dramatically reduced with depth. A similar trend, where the number of crustaceans increased with depth and molluscs became rare in stations deeper than 200 m, was reported for Greek waters (Cretan Sea) by Smith *et al*. (1997).

Although the marketable total catch and the commercial catch of fish and cephalopods was higher in the shallower stratum (300–500 m) during all seasons, the commercial catch of crustaceans was higher in the second stratum (500–700).

The most abundant high value species of the shallower stratum were *M. merluccius, P. longirostris, S. blainvillei* and *L. boscii.* However, this depth zone was characterized by a particularly high abundance of the non-commercial species *C. agassizii,* as well as of the importance of other non-commercial species such as *G. argenteus* and *A. sphyraena*. The C/T ratio of this zone was generally low (<0.5), and even though the marketable catch of this zone was higher compared to deeper waters, the discarded part of the catch was even higher. A factor which may reduce the ratio of commercial/non-commercial species is increasing fishing pressure over time (Overholtz and Tyler, 1985). In the Greek Ionian Sea, fishing activity is carried out mainly down to 400 m and most of the stocks were found to be overexploited (Stergiou *et al*., 1997) down to this depth. Consequently, apart from other factors related to the geomorphology and oceanography of the study area, the commercial fishery may have affected the species composition of the 300–500 m depth zone.

The two deeper zones can be considered as unexploited and in pristine state, since fishing activities do not reach these depths. The most important species for fisheries found in the middle stratum were *H. dactylopterus*, red shrimps (mainly *A. foliacea*), *M. merluccius* and *S. blainvillei*. *H. dactylopterus*, although found in all the depth zones examined, showed its maximum of abundance in the 500-700 m zone during all seasons. Also *A. foliacea,* which was caught in the two deeper strata, was more abundant in the middle zone. Despite the decrease of the total catch in this depth zone, it must be noted that the CPUE of non-commercial species was reduced in this depth zone and the C/T ratio was generally high. Finally, in the deeper zone, both the catch and the C/T ratio were low. However, species of considerable value, such as *A. foliacea, A. antennatus, H. dactylopterus* and *Lophius* spp., were found in non-negligible quantities.

A seasonal trend in the CPUE was observed in all depths, although not significant in the deepest zone, with a minimum in spring and a maximum in autumn in the shallower or in summer in deeper waters. This phenomenon may be attributed to the yearly recruits and to species movements. However, in the shallower zone, the influence of fishing activities on the seasonal variability of the catches could also be considered. The observed minimum CPUE in spring coincides with the end of the trawl-fishing period, whereas the maximum observed CPUE in the autumn in this stratum coincides with the end of the closed season for trawling (1^{st} June to 30^{th} September).

Even though the comparison of species abundance with other Mediterranean studies is difficult, because of the different types of gears and methods used, our results indicate comparable or even higher abundance for some deep-water species of high commercial value. More specifically, in an earlier investigation of the deep waters of the central E. Ionian Sea (Greek waters) the following abundance values were reported for the main species: 0.3–6.4 kg/hr for *H. dactylopterus*, 9.1–20.1 kg/hr for *A. foliacea* and 0.5–7.7 kg/hr for *A. antennatus* (Anon., 1999). From experimental trawling carried out in the Western Ionian Sea (Italian waters), an abundance ranging from 0.3 to 2.3 kg/hr, depending on the season, was reported for *H. dactylopterus* (D'Onghia *et al*., 1998). In the same area, the abundance of *A. foliacea* ranged between 0.3 and 1.6 kg/hr, that of *A. antennatus* between 3.6 and 8.2 kg/hr and finally that of *Lophius* spp. from 1 to 3.3 kg/hr. For the Western Mediterranean (Catalan Sea) a biomass range of 0.03 to 0.2 kg/hr (depth zone 552–1 149 m) was referred for *A. antennatus,* whereas *A. foliacea* was absent (Cartes and Sardà, 1992). Concerning the deep-water red shrimps, more information is given in a recent comparative work based on the results of the MEDITS 1994–99 projects, where a common gear and working protocol was used by all the participants. According to this, although an underestimation of deep-water shrimps was observed in the Greek waters for the first years, probably due to the inexperience of Greek fishermen to deep-water fishing, during the last years, remarkably high biomass indices were found mainly for *A. foliacea* in the Greek waters and the Eastern Ionian Sea (Cau *et al*., 2002). Particularly in 1999, the biomass index obtained for *A. foliacea* in the Eastern Ionian Sea was the highest observed for all the Mediterranean areas under study.

In conclusion, the above results show the existence of important fisheries resources in the deep waters of the Greek Ionian Sea. Species such as *A. foliacea, A. antennatus* and *H. dactylopterus,* which are unknown in most Greek fish markets, are extensively exploited in the Western and Central Mediterranean by deep water trawling down to 1 000 m (Ragonese and Reale, 1992; Ragonese *et al*., 1994; Sardà and Cartes, 1994). The extension of Greek bottom trawling to deeper waters is expected to lead to a reduction in fishing pressure in shallower waters and provide new products to the market. The relatively high proportion of commercial species compared to the discarded part in the deeper waters, zone 500–700 m, encourages their exploitation. Although Greek fishermen are not experienced in deep-water fishing and until recently believed that no marketable resources existed in deeper waters, they showed a high interest to participate in the experimental cruises for training purposes. A few of them have already started an occasional exploitation of red shrimps, which were welcomed in the regional market with relatively low price at the beginning and increasing afterwards. However, a better knowledge of the deep-water species and ecosystem, is required in order to formulate an effective management scheme for deep-water resources and regulate their exploitation in a sustainable way. Deep-water ecosystems are known to be particularly fragile mostly inhabited by slow growing, long lived and late maturing species having low fecundity (Koslow *et al*., 1995; Labropoulou and Papaconstantinou, 2000b; Massutí *et al*., 2000; Clark, 2001; Morales-Nin, 2001). These characteristics make the deep-water species particularly vulnerable to over-exploitation with a slow recovery rate. There are different examples over the world where initially large deep-water stocks decline quite steeply after intensive fisheries exploitation for a few years (Haedrich *et al*., 2001). A similar case in the Mediterranean may be that of *A. foliacea*. This species relatively abundant in the easternmost Mediterranean is absent or rare in the westernmost Mediterranean, where it was previously fished in high quantities (Orsi Relini and Relini, 1985; Relini and Orsi Relini, 1987; Campillo, 1994). Among other explanations given for its distribution pattern along the Mediterranean, over-fishing is considered a major factor that has depleted its stocks westwards (Orsi Relini and Relini, 1985; Relini and Orsi Relini, 1987; Matarrese *et al*., 1997). A management measure that could contribute to the avoidance of such phenomena can be the increase of the minimum mesh size for deep-water trawling, taking also into account the tendency of larger individuals to inhabit deeper waters, known as the bigger-deeper phenomenon (MacPherson and Duarte, 1991). The implemented 20 mm (side) mesh size for the Mediterranean is not selective for important species such as *A. foliacea, A. antennatus, P. longirostris, M. merluccius* and *M. poutassou* (Ragonese and Bianchini, 1996; D'Onghia *et al*., 1998). A mesh size of at least 28–30 mm is proposed. On the other hand, measures such as closed seasons for trawling may be beneficial for the stocks. In particular, the official closure of the trawl fishery in Greek waters every summer (1st June to 30th September) could be beneficial for red shrimps since it coincides with their reproduction period (Anon., 2001; Kapiris and Thessalou-Legaki, 2001).

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