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MEDITERRANEAN MARINE DEMERSAL RESOURCES: THE MEDITS INTERNATIONAL TRAWL SURVEY (1994-1999).
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Distribution and abundance of *Octopus vulgaris* Cuvier, 1797 (Cephalopoda: Octopoda) in the Mediterranean Sea*

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SUMMARY: Information on distribution, abundance and size composition of the common octopus *Octopus vulgaris* was obtained from the MEDITS trawl surveys, carried out in a wide area of the Mediterranean basin from 1994 to 1999. The species showed a wide geographic distribution, since it was collected in all the major areas investigated, but differences were highlighted among the 40 geographic sectors sampled. *O. vulgaris* showed a narrow depth distribution, mostly restricted to within 100 m. Catches below 200 m were scarce and occasional at deeper sea bottoms. Further analysis between major areas in the depth strata 10-50 m and 50-100 m showed the Alborán Sea and Sardinian waters as the areas where the abundance of the species was the greatest. Size frequency distributions showed a wide size range, even if large individuals were represented in a very low proportion. The surveys highlighted the relevant presence of small individuals in almost all the analysed areas. Recruits with a modal length of 5-6 cm mantle length constituted the dominant mode in the histograms of a great extent of the Italian coasts and in Morocco and Corsica waters.

Key words: *Octopus vulgaris*, distribution, abundance, size composition, trawl surveys, MEDITS, Mediterranean Sea.

INTRODUCTION

The common octopus, *Octopus vulgaris* Cuvier, 1797, is a benthic cephalopod distributed on rocky, sandy and muddy bottoms from the coastline to the edge of the continental shelf (Mangold, 1983; Belcari and Sartor, 1999). This species has been long considered of cosmopolitan occurrence in temperate and tropical seas (Roper *et al*., 1984), but a possible occurrence of cryptic species among *O. vulgaris*-like octopods is also reported (Mangold, 1998; Guerra *et al*., 1999). Thus, the distribution of *O. vulgaris* in a strict sense may be restricted to the Mediterranean Sea and eastern Atlantic Ocean (Mangold, 1998).

The species is of great concern as an exploitable resource and therefore subject to intense fishing activity carried out mainly by various small-scale gears, such as traps, pots, fyke-nets and set-nets (Würtz and Repetto, 1983; Sánchez and Obarti,

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1993; Belluscio and Ardizzone, 1990), altough in the Mediterranean basin, octopus catches constitute an important fraction of the commercial landings of trawlers operating on the continental shelf (Tursi and D'Onghia, 1992; Belcari and Sartor, 1993; Quetglas *et al.,* 1998). According to FAO statistics, the world annual landings of *O. vulgaris* were about 165,000 tons in 1996 (FAO, 1998). Despite this great commercial interest, studies defining distribution and abundance of stocks are still lacking in many areas. The species is often pooled together with *Eledone cirrhosa* and *Eledone moschata* in the commercial landings and in the Mediterranean fishery statistics (Sánchez and Martín, 1993; Belcari *et al*., 1998; Lefkaditou *et al.,* 2000). This makes it impossible to assess individual catch levels as an index of stock biomass based on the assessment of landing data and statistics. To date there is still a lack of basic information for the correct management of this resource.

The present paper aims at contributing to the knowledge of the distribution, abundance and demographic structure of *O. vulgaris* collected by means of experimental trawl surveys carried out with a common methodology in a wide area of the Mediterranean basin.

MATERIALS AND METHODS

Sampling

Six annual bottom trawl surveys that were mainly aimed at obtaining estimates of abundance indices for a series of demersal target species were carried out from late spring to mid summer in the Mediterranean Sea from 1994 to 1999 (Bertrand *et al*., 2000, 2002). The surveys covered 40 sub-areas belonging to 15 major areas (Table 1); Morocco was included in the project in 1999. A total of approximately 1,000 hauls was made during each survey in the depth range 10-800 m, by means of a standard trawl net GOC 73 having a cod-end mesh opening of 20 mm. Selection of sampling stations was based on a depth-stratified sampling scheme taking into account the surface area of each stratum; five depth zones were considered: 10-50, 50-100, 100-200, 200-500 and 500-800 m. Specimens were counted, weighed, measured (mantle length, ML, to the next lower 0.5 cm) sexed and assigned to a maturity stage by macroscopic analysis of the gonads. The same sampling protocol was used in all cases (see Bertrand *et al*., 2000, 2002).

TABLE 1. – List of the major areas covered by the surveys. *Area 114 was not included in the analysis as only one-year data were available. A map of all the area sampled can be found in Bertrand *et al.,* 2000, 2002).

Area Code	Area name
111	Alborán Sea
112	Alicante region
113	Catalan Sea
114*	Morocco
121	Gulf of Lion
131	Corsican Sea
132	Ligurian, N and Central Tyrrhenian Sea
133	Sardinian Sea
134	S Tyrrhenian Sea and Sicilian Channel
211	N and Central Adriatic Sea
221	S Adriatic and W Ionian Sea
222	E Ionian Sea
223	Argosaronikos region
224	N Aegean Sea
225	S Aegean Sea

Data analysis

Catch data (number and weight) of specimens collected were analysed by means of specifically developed software (Souplet, 1996). In order to obtain estimates of abundance indices expressed in terms of both number of specimens and kg per km^2, the surface of each sub-area and depth stratum was taken into account. The abundance estimations of the species were calculated as a mean value per year of sampling, geographic sector and bathymetric stratum.

Abundance and biomass indices were compared between strata and the interaction of year effect on the indices was evaluated, using two-way ANOVA and *post hoc* contrast analysis (Zar, 1984). In order to help normalize density indices (n/km^2) and biomass indices (kg/km^2) from heteroscedasticity, indices were log-transformed (log (x+1)) before ANOVA, thus eliminating the correlation between means and standard deviations, making the statistical analysis more robust (Zar, 1984). Pairwise comparisons, based on both indices, were made using the Scheffé test. The above estimates indicated that the abundance of *O. vulgaris* was negligible in waters deeper than 100 m. For this reason further analysis was confined to depth strata down to 100 m.

The mean density indices between areas were compared by one-way ANOVA in the depth strata where the species was more abundant, 10-50 m and 50-100 m. Using the Tukey (HSD) test, for unequal sample sizes, pairwise comparisons between areas

TABLE 2. – *Octopus vulgaris*: Mean density (n/km^2) estimated from the MEDITS trawl surveys by depth stratum, geographical sector and year (1994-1999). Not sampled strata are indicated by '*'. Values higher than 200 n/km^2 are presented in bold.

Sector code	Sector	1994 Depth (m) 10-50	50-100	100-200	200-500	500-800	1995 Depth (m) 10-50	50-100	100-200	200-500	500-800	1996 Depth (m) 10-50	50-100	100-200	200-500	500-800
111a	Alborán Sea	138	**232**	44	0	0	117	114	0	2	0	195	158	30	0	0
112a	Alicante	**329**	36	0	0	0	153	36	5	0	0	138	47	20	0	0
113a	Catalan Sea	6	2	0	0	0	**246**	6	7	0	0	70	12	6	0	0
114a	W Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
114b	E Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
121a	W Gulf of Lions	41	20	42	5	0	51	12	9	0	0	54	16	0	7	0
121b	E Gulf of Lions	72	9	27	0	0	14	3	0	0	0	76	7	2	0	0
131a	NE Corsica	*	41	0	0	0	*	36	10	0	0	*	0	0	0	0
131b	SE Corsica	*	22	33	0	0	*	21	84	0	0	*	46	186	3	0
132a	N Ligurian Sea	15	26	0	0	0	0	0	6	0	0	31	39	0	0	0
132b	E Ligurian Sea	3	7	0	0	0	0	10	0	0	0	3	26	6	0	0
132c	N Tyrrhenian	49	9	0	0	0	92	7	0	0	0	119	19	0	0	0
132d	C Tyrrhenian	48	11	0	0	0	64	0	0	0	0	122	7	0	0	0
133a	SE Sardinia	139	68	12	0	0	**256**	144	0	0	0	**207**	**266**	0	0	0
133b	NE Sardinia	119	85	11	0	0	189	25	0	0	0	**226**	36	0	0	0
133c	N Sardinia	118	32	0	0	0	175	181	0	0	0	104	**265**	0	0	0
133d	NW Sardinia	**220**	9	0	0	0	*	21	0	0	0	24	10	0	0	0
133e	W Sardinia	50	*	0	0	0	52	22	4	0	0	89	126	0	0	0
133f	SW Sardinia	62	110	0	0	0	168	35	5	2	0	**250**	51	2	0	0
133g	S Sardinia	0	128	10	0	0	12	*	37	0	0	**296**	34	0	0	0
134a	SE Tyrrhenian	18	4	6	0	0	23	0	2	0	0	52	0	0	0	0
134b	SW Tyrrhenian	16	6	44	0	0	33	16	0	0	0	29	28	10	0	0
134c	Sicilian Chan.	24	18	33	1	0	11	13	3	0	0	40	24	0	0	0
211a	N Adriatic Sea	0	0	*	*	*	1	2	*	*	*	0	3	*	*	*
211b	Central Adriatic	0	0	0	0	0	2	0	0	0	0	11	2	0	0	0
211c	N Adriatic-Slov	*	*	*	*	*	0	*	*	*	*	0	*	*	*	*
211d	NE Adri Croatia	*	*	*	*	*	*	*	*	*	*	2	10	0	0	*
221a	E Sicily	0	0	29	0	0	8	0	7	0	0	22	0	0	0	0
221b	NW Ionian Sea	0	11	0	0	0	12	0	0	0	0	11	0	0	0	0
221c	N Ionian Sea	24	15	0	0	0	52	0	0	0	0	14	14	0	0	0
221d	N Ionian Sea	*	0	0	0	0	21	0	0	0	0	21	19	7	0	0
221e	SW Adriatic	0	13	0	0	0	*	14	0	0	0	*	0	0	0	0
221f	SW Adriatic	20	0	0	0	0	38	15	0	0	0	7	7	4	0	0
221g	SW Adriatic	12	0	0	*	0	11	0	0	*	0	0	0	0	*	0
221h	SW Adriatic	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
221i	SE Adriatic	*	*	*	*	*	*	*	*	*	*	15	4	0	0	0
222a	E Ionian Sea	0	0	0	0	0	18	18	0	0	0	80	22	8	0	0
223a	Argosaronikos	74	0	0	0	0	92	17	0	0	0	154	55	0	0	0
224a	N Aegean Sea	20	14	3	0	0	137	4	0	1	0	**251**	25	0	5	0
225a	S Aegean Sea	32	59	11	3	0	9	5	6	0	0	63	24	9	1	0

Sector code	Sector	1997 Depth (m) 10-50	50-100	100-200	200-500	500-800	1998 Depth (m) 10-50	50-100	100-200	200-500	500-800	1999 Depth (m) 10-50	50-100	100-200	200-500	500-800
111a	Alborán Sea	77	121	85	0	0	137	120	15	0	0	22	56	29	0	0
112a	Alicante	137	70	15	0	0	133	14	8	0	0	**246**	77	13	0	0
113a	Catalan Sea	70	5	17	0	0	49	1	0	*	0	72	6	0	0	0
114a	W Morocco	*	*	*	*	*	*	*	*	*	*	*	130	**305**	0	0
114b	E Morocco	*	*	*	*	*	*	*	*	*	*	**724**	19	63	1	0
121a	W Gulf of Lions	10	9	45	0	0	35	4	0	110	0	90	19	21	0	0
121b	E Gulf of Lions	40	1	2	0	0	58	2	0	0	0	291	4	11	0	*
131a	NE Corsica	*	0	*	0	0	*	28	0	0	0	*	0	80	8	0
131b	SE Corsica	*	108	7	0	*	*	9	9	3	0	*	**249**	47	0	0
132a	N Ligurian Sea	20	16	0	0	0	22	0	0	0	0	54	7	5	0	0
132b	E Ligurian Sea	11	19	0	0	0	5	16	10	0	0	3	40	18	0	0
132c	N Tyrrhenian	104	16	8	0	0	104	7	0	0	0	118	9	2	0	0
132d	C Tyrrhenian	110	0	1	0	0	122	7	5	0	0	47	3	1	0	0
133a	SE Sardinia	175	141	0	0	0	143	104	11	0	0	**295**	**214**	0	0	0
133b	NE Sardinia	**294**	77	11	0	0	182	**272**	0	0	0	**261**	**217**	0	0	0
133c	N Sardinia	**294**	126	0	0	0	**467**	117	15	0	0	**576**	**265**	0	0	0
133d	NW Sardinia	**380**	31	0	0	0	124	46	0	0	0	49	51	4	0	0
133e	W Sardinia	121	74	0	0	0	96	14	4	0	0	**303**	135	0	0	0
133f	SW Sardinia	128	117	2	1	0	175	103	4	0	0	172	183	14	1	0
133g	S Sardinia	**347**	0	6	0	0	129	115	5	0	0	**884**	155	9	0	0
134a	SE Tyrrhenian	16	7	0	0	0	50	0	2	0	0	11	7	9	0	0
134b	SW Tyrrhenian	40	33	3	0	0	35	22	3	0	0	32	0	0	0	0
134c	Sicilian Chan.	68	35	0	1	0	107	25	2	0	0	51	30	0	0	0

TABLE 2 (Cont.). – *Octopus vulgaris*: Mean density (n/km^2) estimated from the MEDITS trawl surveys by depth stratum, geographical sector and year (1994-1999). Not sampled strata are indicated by '*'. Values higher than 200 n/km^2 are presented in bold.

		1997 Depth (m)					1998 Depth (m)					1999 Depth (m)				
Sector code	Sector	10-50	50-100	100-200	200-500	500-800	10-50	50-100	100-200	200-500	500-800	10-50	50-100	100-200	200-500	500-800
211a	N Adriatic Sea	2	0	*	*	*	1	0	*	*	*	0	2	*	*	*
211b	Central Adriatic	6	2	0	0	0	0	0	0	0	*	9	2	2	2	*
211c	N Adriatic-Slov	0	*	*	*	*	0	*	*	*	*	0	*	*	*	*
211d	NE Adri Croatia	2	9	0	0	*	2	8	0	0	*	0	*	*	*	*
221a	E Sicily	23	10	8	0	0	30	45	8	4	0	8	0	7	0	0
221b	NW Ionian Sea	0	11	0	4	0	11	11	0	0	0	11	0	0	0	0
221c	N Ionian Sea	15	0	0	0	0	7	7	0	0	0	0	0	0	0	0
221d	N Ionian Sea	22	0	0	0	0	22	0	0	0	0	25	0	0	0	0
221e	SW Adriatic	*	0	0	0	0	*	0	0	0	0	*	7	6	0	0
221f	SW Adriatic	16	22	4	0	0	8	8	0	0	0	173	52	4	0	0
221g	SW Adriatic	12	0	0	*	0	0	0	0	*	0	35	15	0	*	0
221h	SW Adriatic	20	0	0	0	0	8	0	0	0	0	10	11	3	3	0
221i	SE Adriatic	0	2	2	0	0	22	4	0	0	0	8	0	52	10	0
222a	E Ionian Sea	105	20	21	0	0	41	18	4	0	0	10	23	7	0	0
223a	Argosaronikos	28	34	6	0	0	60	39	3	0	0	91	130	0	0	0
224a	N Aegean Sea	77	21	5	1	0	127	10	3	0	0	41	13	4	1	0
225a	S Aegean Sea	96	36	16	1	0	125	23	22	1	0	62	26	8	1	0

Table 3.- *Octopus vulgaris*: Mean biomass (kg/km^2) estimated from the MEDITS trawl surveys by depth stratum, geographical sector and year (1994-1999). Not sampled strata are indicated by '*'. Values higher than 150 kg/km^2 are presented in bold.

		1994 Depth (m)					1995 Depth (m)					1996 Depth (m)				
Sector code	Sector	10-50	50-100	100-200	200-500	500-800	10-50	50-100	100-200	200-500	500-800	10-50	50-100	100-200	200-500	500-800
111a	Alborán Sea	**169.8**	**151.0**	20.3	0	0	98.2	106.9	0	4.4	0	57.4	131.8	15.4	0	0
112a	Alicante	**152.1**	31.0	0	0	0	102.2	41.2	7.2	0	0	104.1	43.6	23.4	0	0
113a	Catalan Sea	9.9	3.5	0	0	0	113.2	6.7	2.7	0	0	14.7	5.6	5.7	0	0
114a	W Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
114b	E Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
121a	W Gulf of Lions	32.4	7.4	14.7	6.4	0	70.3	12.0	0.5	0	0	58.3	13.2	0	0.4	0
121b	E Gulf of Lions	52.8	8.3	1.1	0	0	34.7	0.1	0	0	0	63.1	18.0	0.2	0	0
131a	NE Corsica	*	14.7	0	0	0	*	11.2	1.3	0	0	*	0	0	0	0
131b	SE Corsica	*	7.5	1.5	0	0	*	7.1	4.5	0	0	*	3.0	47.4	0	0
132a	N Ligurian Sea	26.4	24.1	0	0	0	0	0.0	1.3	0	0	28.9	49.7	0	0	0
132b	E Ligurian Sea	2.5	1.5	0	0	0	0	6.5	0	0	0	0.3	19.0	3.1	0	0
132c	N Tyrrhenian	43.7	9.2	0	0	0	54.1	2.8	0	0	0	95.5	18.5	0	0	0
132d	C Tyrrhenian	16.0	2.2	0	0	0	20.2	0	0	0	0	46.9	10.3	0	0	0
133a	SE Sardinia	125.6	35.5	7.7	0	0	64.9	55.1	0	0	0	109.9	99.2	0	0	0
133b	NE Sardinia	83.5	44.6	2.2	0	0	39.5	7.2	0	0	0	121.6	17.5	0	0	0
133c	N Sardinia	100.2	**202.6**	0	0	0	128.0	100.1	0	0	0	87.3	81.9	0	0	0
133d	NW Sardinia	**156.6**	4.1	0	0	0	*	17.2	0	0	0	12.2	0.8	0	0	0
133e	W Sardinia	28.9	*	0	0	0	44.6	6.7	1.3	0	0	46.5	61.2	0	0	0
133f	SW Sardinia	12.3	49.3	0	0	0	45.6	11.7	2.3	0	0	84.8	20.6	0.7	0	0
133g	S Sardinia	0	53.0	4.8	0	0	0.6	*	4.3	0	0	48.5	6.9	0	0	0
134a	SE Tyrrhenian	9.6	2.2	1.1	0	0	3.4	0.0	1.3	0	0	36.3	0.0	0	0	0
134b	SW Tyrrhenian	4.1	5.7	1.4	0	0	0.7	13.4	0	0	0	4.7	18.1	6.7	0	0
134c	Sicilian Chan.	26.3	13.8	2.5	1.6	0	7.6	14.5	2.8	0	0	25.2	17.0	0	0	0
211a	N Adriatic Sea	0	0	*	*	*	0.3	1.5	*	*	*	0	2.6	*	*	*
211b	Central Adriatic	0	0	0	0	0	2.3	0	0	0	0	18.1	0.3	0	0	0
211c	N Adriatic-Slov	*	*	*	*	*	0	*	*	*	*	0	*	*	*	*
211d	NE Adri Croatia	*	*	*	*	*	*	*	*	*	*	1.2	6.2	0	0	*
221a	E Sicily	0	0	17.5	0	0	0.2	0	11.2	0	0	1.1	0	0	0	0
221b	NW Ionian Sea	0	5.6	0	0	0	32.6	0	0	0	0	24.0	0	0	0	0
221c	N Ionian Sea	10.2	0.8	0	0	0	105.1	0	0	0	0	0.6	34.5	0	0	0
221d	N Ionian Sea	*	0	0	0	0	12.6	0	0	0	0	0.5	5.7	8.1	0	0
221e	SW Adriatic	0.0	11.6	0	0	0	*	20.3	0	0	0	*	0	0	0	0
221f	SW Adriatic	32.9	0	0	0	0	42.5	0.5	0	0	0	12.0	13.5	12.1	0	0
221g	SW Adriatic	22.0	0	0	*	0	23.2	0	0	*	0	0	0	0	*	0
221h	SW Adriatic	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0
221i	SE Adriatic	*	*	*	*	*	*	*	*	*	*	2.8	10.7	0	0	0
222a	E Ionian Sea	0	0	0	0	0	2.7	29.3	0	0	0	43.7	11.1	1.7	0	0
223a	Argosaronikos	47.1	0	0	0	0	33.3	4.3	0	0	0	81.5	55.2	0	0	0
224a	N Aegean Sea	10.8	6.6	1.8	0	0	69.7	11.3	0	1.5	0	117.7	23.2	0	1.5	0
225a	S Aegean Sea	38.4	45.5	15.2	4.2	0	12.3	2.3	4.6	0	0	53.0	29.6	6.5	0.6	0

Table 3.- *Octopus vulgaris*: Mean biomass (kg/km^2) estimated from the MEDITS trawl surveys by depth stratum, geographical sector and year (1994-1999). Not sampled strata are indicated by '*'. Values higher than 150 kg/km^2 are presented in bold.

		1997 Depth (m)					1998 Depth (m)					1999 Depth (m)				
Sector code	Sector	10-50	50-100	100-200	200-500	500-800	10-50	50-100	100-200	200-500	500-800	10-50	50-100	100-200	200-500	500-800
111a	Alborán Sea	53.9	115.6	81.4	0	0	96.6	79.4	8.5	0	0	10.8	52.2	7.4	0	0
112a	Alicante	116.9	60.6	5.7	0	0	116.0	14.6	1.9	0	0	**175.5**	102.7	11.4	0	0
113a	Catalan Sea	59.4	5.3	6.2	0	0	46.1	0.5	0	*	0	63.8	4.1	0.0	0	0
114a	W Morocco	*	*	*	*	*	*	*	*	*	*	*	135.6	**290.8**	0	0
114b	E Morocco	*	*	*	*	*	*	*	*	*	*	**245.5**	13.4	23.0	0.5	0
121a	W Gulf of Lions	11.4	4.9	1.9	0	0	17.1	4.6	0	36.2	0	73.4	8.2	37.6	0	0
121b	E Gulf of Lions	10.8	5.5	8.2	0	0	68.7	2.2	0	0	0	**261.2**	6.9	0.6	0	*
131a	NE Corsica	*	0	*	0	0	*	2.5	0	0	0	*	0	12.7	0.8	0
131b	SE Corsica	*	16.8	0.2	0	*	*	1.3	0.4	0.1	0	*	87.2	2.0	0	0
132a	N Ligurian Sea	3.9	6.4	0	0	0	44.4	0	0	0	0	52.4	3.9	29.5	0	0
132b	E Ligurian Sea	0.7	8.6	0	0	0	6.0	6.1	6.5	0	0	6.0	24.2	11.9	0	0
132c	N Tyrrhenian	51.3	10.6	8.5	0	0	14.8	0.3	0	0	0	45.9	12.4	1.7	0	0
132d	C Tyrrhenian	46.9	0	0.2	0	0	25.1	0.7	4.3	0	0	19.4	2.3	0.9	0	0
133a	SE Sardinia	49.9	92.3	0	0	0	112.1	35.4	5.8	0	0	116.4	79.9	0	0	0
133b	NE Sardinia	117.1	43.1	4.4	0	0	107.4	142.5	0	0	0	162.3	115.5	0	0	0
133c	N Sardinia	135.3	68.7	0	0	0	**238.0**	69.1	11.9	0	0	**396.4**	**155.6**	0	0	0
133d	NW Sardinia	**234.5**	17.0	0	0	0	86.7	15.3	0.0	0	0	23.5	26.9	3.0	0	0
133e	W Sardinia	40.7	16.4	0	0	0	55.5	10.8	2.1	0	0	**154.9**	56.2	0	0	0
133f	SW Sardinia	36.5	37.1	0.4	1	0	55.8	42.0	1.6	0	0	66.2	56.6	6.8	0.6	0
133g	S Sardinia	59.7	0.0	1.9	0	0	58.2	138.4	4.1	0	0	**614.7**	89.3	5.0	0	0
134a	SE Tyrrhenian	24.3	5.0	0	0	0	65.0	0	0.1	0	0	1.8	7.4	2.5	0	0
134b	SW Tyrrhenian	11.8	20.7	0.1	0	0	23.6	7.7	0.5	0	0	23.8	0	0	0	0
134c	Sicilian Chan.	13.0	25.7	0	0.4	0	30.4	11.0	1.5	0	0	13.6	22.5	0.0	0	0
211a	N Adriatic Sea	3.8	0	*	*	*	3.2	0	*	*	*	0	0.9	*	*	*
211b	Central Adriatic	0.7	1.6	0	0	0	0	0	0	0	*	8.3	2.5	0.5	0.1	*
211c	N Adriatic-Slov	0	*	*	*	*	0	*	*	*	*	0	*	*	*	*
211d	NE Adri Croatia	0.2	4.6	0	0	*	0.4	4.9	0	0	*	0	*	*	*	*
221a	E Sicily	5.5	11.5	4.7	0	0	63.7	39.8	6.5	2.8	0	2.0	0	10.3	0	0
221b	NW Ionian Sea	0.0	54.4	0	3.1	0	20.6	16.1	0	0	0	1.7	0	0	0	0
221c	N Ionian Sea	5.5	0	0	0	0	4.5	7.3	0	0	0	0	0	0	0	0
221d	N Ionian Sea	34.6	0	0	0	0	13.2	0	0	0	0	18.0	0	0	0	0
221e	SW Adriatic	*	0	0	0	0	*	0	0	0	0	*	4.0	0.1	0	0
221f	SW Adriatic	1.0	4.5	5.6	0	0	14.2	0.8	0	0	0	19.9	7.7	3.0	0	0
221g	SW Adriatic	0.3	0	0	*	0	0	0	0	*	0	3.0	8.5	0	*	0
221h	SW Adriatic	11.4	0	0	0	0	8.8	0	0	0	0	2.7	7.0	2.5	0.3	0
221i	SE Adriatic	0.0	4.6	1.3	0	0	25.8	0.7	0	0	0	0.4	0.0	2.2	0.2	0
222a	E Ionian Sea	43.7	12.8	2.4	0	0	13.9	23.3	0.1	0	0	13.4	10.4	11.7	0	0
223a	Argosaronikos	23.6	57.9	2.3	0	0	56.5	36.1	1.0	0	0	90.2	62.2	0	0	0
224a	N Aegean Sea	43.3	24.3	6.3	0.8	0	63.7	3.5	0.8	0	0	24.1	13.5	4.1	0.4	0
225a	S Aegean Sea	31.8	36.5	6.4	0.1	0	69.0	8.3	3.2	0.4	0	16.1	22.4	3.9	1.7	0

indicated the homogeneous group of areas in the Mediterranean basin.

Statistical analysis was performed with the package *STATISTICA* (release 6).

The demographic structure of the species was firstly studied by computing the size frequency distributions for every major area (see Table 1). All the years were pooled, since the cruises were always performed at the same period of the year. Due to the narrow distribution and to the scarcity of catches**,** almost all the length frequency histograms considered here resulted from grouping together data coming from areas of the same country, when non-significant differences were found. Length frequency distributions in major areas were compared by means of the Kolmogorov-Smirnov test. Furthermore, samples that during the six years of study did not exceed 50 specimens were excluded (area 211).

RESULTS

Abundance indices

Octopus vulgaris was distributed along the whole western Mediterranean basin, even if in a discontinuous way; in the central basin the species was fairly sparse, appearing only as a few individuals per square km, or not at all, in the Adriatic and northern and north western Ionian sea, and slightly increasing again in the eastern Mediterranean (Tables 2 and 3). The species showed a narrow depth distribution, mostly restricted within 100 m; below 200 m, catches were scarce and at further depths, occasional.

The species abundance and bathymetric distribution were evaluated by comparing the variation of density and biomass indices between the five depth zones in the years 1994-1999, using two-way

TABLE 4. – Two-way ANOVA, fixed effects, summary table of *O. vulgaris* log-transformed density indices, indicating the sources of variance: Depth (5 depth strata), Year (6 years, 1994-1999) and Depth x Year interaction.

Source of variance	df Effect	MS Effect	df Error	MS Error	F	p-level
Depth	4	82.55	1013	0.31	272.84	0.0000
Year	5	0.87	1013	0.30	2.88	0.0136
Depth x Year *interaction*	20	0.22	1013	0.30	0.73	0.7986

TABLE 5. – Two-way ANOVA, fixed effects, summary table of *O. vulgaris* log-transformed biomass indices, indicating the sources of variance: Depth (5 depth strata), Year (6 years, 1994-1999) and Depth x Year interaction.

Source of variance	df Effect	MS Effect	df Error	MS Error	F	p-level
Depth	4	61.18	1013	0.25	249.28	0.0000
Year	5	0.57	1013	0.25	2.33	0.0410
Depth x Year interaction	20	0.21	1013	0.25	0.87	0.6281

ANOVA design, 5 (depth zones) x 6 (years), without taking into account the effect of different sectors (Tables 4 and 5). According to these tables, there was no interaction effect between the variables, that is, the effect of depth on the abundance and biomass indices was not affected by the effect of year ($p>0.05$), while significant differences ($p<0.001$) among the depth zones were estimated. Figure 1 shows that the shallower the bathymetric zone the more abundant the species. Pairwise comparisons indicated that the mean abundance indices were different among all the depth zones ($p<0.001$), except those between the two deeper zones, 200-500 m and 500-800 m ($p>0.05$), where the lowest abundance indices were computed (Fig. 1).

Mean density indices were compared among major areas in the depth strata 10-50 m and 50-100 m. ANOVA detected significant differences between areas ($p<0.001$) for both depth strata. The *post hoc* procedure was used to explain any pattern of means and to test their statistical significance. Pairwise comparisons between areas indicated the occurrence of three homogeneous groups of areas in the zone 10-50 m and 50-100 m (Table 6). According to the table, in the depth stratum 10-50 m there were no clear distinct groups of areas, except that of the northern and central Adriatic Sea (area 211), which showed very low abundance indices in comparison to the other ones. The group 2 consisted of areas with generally lower mean abundance values in comparison to the group 3. Areas not belonging contemporarily to groups 2 and 3 stand out from the others. As a matter of fact, the Alborán Sea, Alicante sector, Gulf of Lions and Sardinian waters (areas 111, 112, 121, 133), showed constantly higher densities, while the area 221, south Adriatic Sea and western Ionian Sea, showed the lowest values in the group. For the stratum 50-100 m, the first group, consisting of 11 areas, and the third one, consisting of 9 areas, presented the lowest and the highest mean abundance values, respectively. Alborán Sea and Sardinian waters remained the areas where the greatest abundance of the species was found.

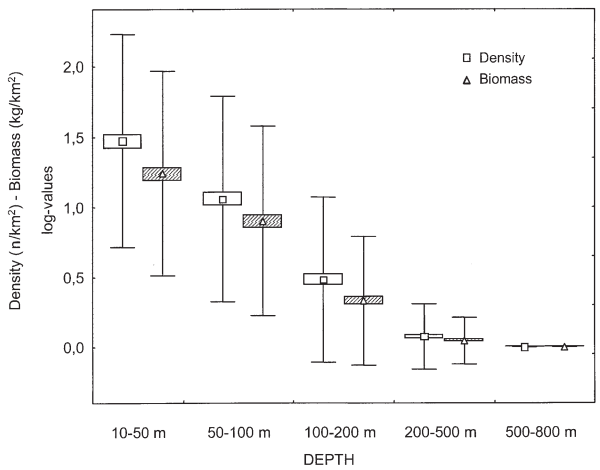

FIG. 1. – Density and biomass indices of *Octopus vulgaris* in the different sampled bathymetric strata. Mean; Box: Mean ± Standard Error; Whisker: Mean ± Standard Deviation.

Size structure

Length composition analysis of *O. vulgaris* in the 10 areas considered, showed, in most cases, sizes comprised between 3 and 20 cm ML (Fig. 3).

Small individuals were present in the entire study area. The smallest specimens (1 cm ML) were found in the Catalan Sea (area 113), while the maximum

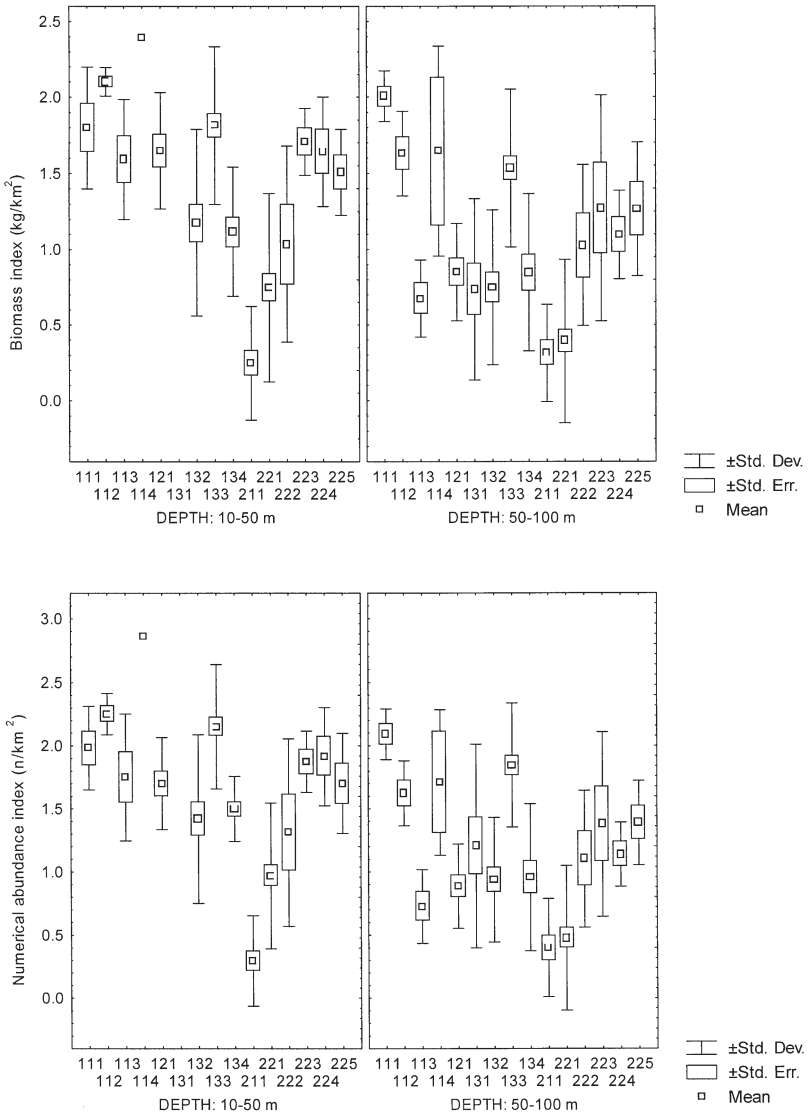

FIG. 2. – Numerical abundance and biomass indices of *Octopus vulgaris* in the major areas (see Table 1) for the bathymetric strata 10-50 m and 50-100 m. Mean values (Mean); standard errors (Std. Err.); standard deviations (Std. Dev.).

TABLE 6. – Homogeneous groups of means of log-transformed density indices based on Tukey test, for unequal sample size. In each column 1, 2 and 3 homogeneous groups of means (those that are not significantly different from each other) are indicated by X in the respective rows. All means that are not identified as members of the same homogeneous group are significantly different from each other at $p<0.05$.

		Depth: 10-50 m					Depth: 50-100 m		
Area	Mean	1	2	3	Area	Mean	1	2	3
211	0.30	X			211	0.40	X		
221	0.97		X		221	0.48	X		
222	1.31		X	X	113	0.73	X	X	
132	1.42		X	X	121	0.89	X	X	
134	1.50		X	X	132	0.94	X	X	
121	1.70			X	134	0.96	X	X	
225	1.70		X	X	222	1.10	X	X	X
113	1.75		X	X	224	1.14	X	X	X
223	1.87		X	X	131	1.21		X	X
224	1.91		X	X	223	1.38	X	X	X
111	1.98			X	225	1.39	X	X	X
133	2.15			X	112	1.62		X	X
112	2.25			X	114	1.71	X	X	X
114	2.86		X	X	133	1.85			X
					111	2.09			X

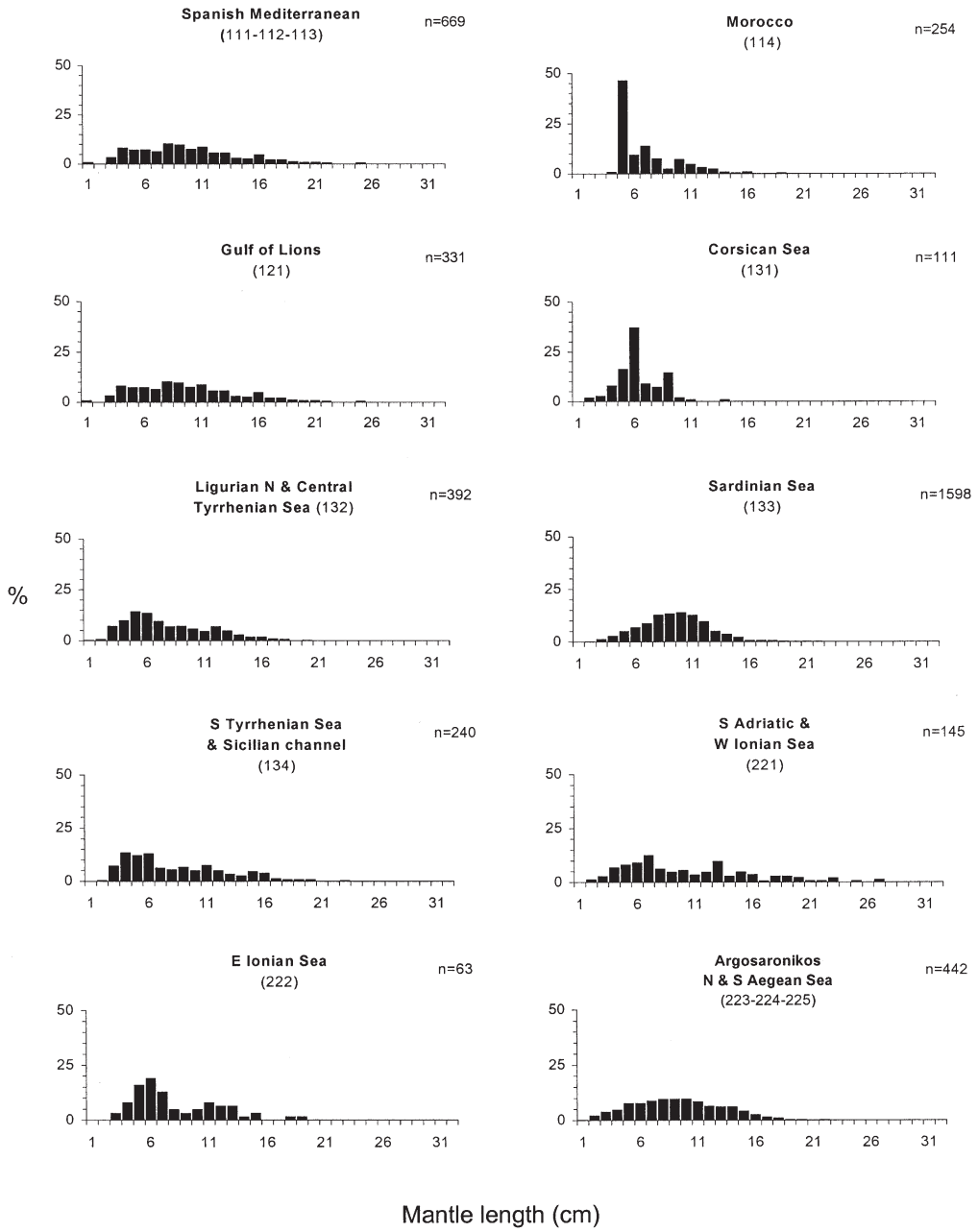

FIG. 3. – Overall length frequency distributions of *Octopus vulgaris* in 10 areas of the Mediterranean Sea (see Table 1).

size (27 cm ML) was recorded in the Ionian Sea (eastern Sicily). Recruits with modal length of 5-6 cm ML constituted the dominant mode in the Ligurian and Tyrrhenian seas, Sicilian Channel, south Adriatic and Ionian Sea (areas 132, 134, 221 and 222). In Morocco and Corsican waters (areas 114, 131) recruits represented up to 50 % of the entire sampled population.

The pairwise comparisons of length frequency distributions made by the Kolmogorov-Smirnov test revealed significant differences ($p < 0.05$) among all samples analysed.

DISCUSSION

Octopus vulgaris is undoubtedly one of the best known cephalopod species. It has been the object of a number of studies, related mainly to its biology, ecology, behaviour and physiology (Voss, 1977; Wells, 1978; Mangold 1983; Villanueva, 1995). Despite this fact, field studies are still limited to few areas (Belcari and Sartor, 1999). The MEDITS project allowed the collection of field data in a wide area of the Mediterranean, thus providing useful information on distribution, demographic structure

and abundance estimates from areas not yet widely investigated. As a matter of fact, it is well known that the species is exploited mainly by small scale gears, targeted to catch large individuals. However, octopus catches are consistent in trawl landings as well, and have undergone a considerable increase as a consequence of the improvement of fishing techniques, like the introduction of the so-called "French net", a bottom trawl net with a large vertical opening (Belcari *et al*., 1998). When using otter trawls, captures are possible for that part of the population living on soft, sandy or muddy, bottoms.

The MEDITS trawl surveys confirm the wide geographical distribution of the species: *O. vulgaris* was collected in the all major areas investigated, although notable differences were evidenced among the 40 geographic sectors. Depth distribution, mostly restricted within 200 m, but with greatest densities in the shallowest 100 m, confirmed data already reported in the literature for the Mediterranean (see Belcari and Sartor, 1999, for a review). The spatial distribution followed a patchy pattern, with noticeable fluctuations among areas. The highest abundances were detected around the Sardinian coasts, the Alborán Sea, the Alicante region and Morocco, whereas the lowest abundances were found in the Adriatic Sea. Arguably, low or high densities of the species could be correlated with scarcity or abundance of rocky bottoms, essential for the development of all the phases of the life cycle of the species.

Size frequency distributions of *O. vulgaris* showed a wide size range. The maximum length registered was 27 cm ML. The same size is reported as the longest one in other areas of the Mediterranean (Sánchez and Obarti, 1993). However, large individuals were present in a very low proportion. As a matter of fact, it is known that trawling captures all sizes, but especially the small ones (Sánchez and Obarti, 1993). Considering that mature males are reported from 6.5 ML, but that the majority of them become mature at larger sizes, and that mature females are reported from 13 cm ML (Ruby and Knudsen; 1972; Belcari and Sartor, 1993; Sánchez and Obarti, 1993), it appears that most of the population sampled was constituted by immature specimens. This is probably a consequence of various factors: (a) samplings refer to only one season of the year, when largest octopuses progressively disappear from trawling grounds, mainly as a consequence of migration to rocky bottoms and coastal habitats for spawning (Mangold-Wirz, 1963; Mangold, 1983); (b) unsuitability of the trawl net to capture large, mature individuals.

Investigations carried out in the Thracian Sea during May-July on sandy, muddy bottoms and *Posidonia oceanica* meadows within 35 m depth, using fyke nets and pots (Kallianiotis *et al.,* 2001) showed that the majority of the trapped individuals (99.45%) were fully mature, with a modal mantle length of 14-15 cm.

The MEDITS surveys highlighted the relevant presence of small individuals in almost all analysed areas; the dominant mode of 5-6 cm ML in the histograms of a great extent of the Italian coasts and, above all, in Morocco and Corsica waters, correspond to the cohort of trawl net recruits. Taking into account that MEDITS samplings were mostly carried out from May-June onwards, this result confirms previous data reporting the presence of juveniles in the summer period in the Ligurian and Tyrrhenian seas (Relini and Orsi Relini, 1984; Belluscio and Ardizzone, 1990). The different patterns showed in the other analysed areas, where higher modes were evidenced or where it was not possible to single out a predominant size, could be variously interpreted. In the Mediterranean, the reproductive period of *O. vulgaris* seems to extend almost throughout the year, from January-March to July-October, with one or more spawning peaks (Mangold-Wirz, 1963; Mangold and Boletzky, 1973; Guerra, 1975; Sánchez and Obarti, 1993). As a consequence of a prolonged spawning season and long brooding period, a wide size range can be detected and support the existence of cohorts with different growth rates depending on the hatching period, as proposed for other cephalopod species (Boyle, 1983; Mangold, 1983; Belcari, 1996). Furthermore, postponements of the maturity peaks could lead to different compositions of the demographic structure of the sampled population. Finally, a not perfectly synchronous sampling in the different MEDITS areas of a species characterized by a short life span and high growth rate and having a reproductive period which is hard to be defined (Nixon, 1969; Guerra, 1992), could be partly responsible for some of the differences shown in the present study.

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