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MEDITERRANEAN MARINE DEMERSAL RESOURCES: THE MEDITS INTERNATIONAL TRAWL SURVEY (1994-1999).
P. ABELLÓ, J.A. BERTRAND, L. GIL DE SOLA, C. PAPACONSTANTINOU, G. RELINI and A. SOUPLET (eds.)

Distribution, abundance and biological features of anglerfish (*Lophius piscatorius* and *Lophius budegassa*) (Osteichthyes: Lophiiformes) in the Mediterranean Sea*

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SUMMARY: The distribution and biological features of anglerfish (*Lophius piscatorius* and *L. budegassa*) in the Mediterranean Sea were analysed from trawl surveys data (MEDITS project, years 1994-1999). The above-mentioned species were widely distributed in the Mediterranean, but differences in abundance were found according to geographic sectors and depths. Most of the collected specimens belonged to the first length cohorts and length distributions also differed at macro-area levels. Mean sizes at female sexual maturity were estimated at 68.5 cm and 66.2 cm total length, respectively for *L. piscatorius* and *L. budegassa*.

Key words: Lophius piscatorius, *Lophius budegassa*, distribution, population structure, length at maturity, Mediterranean Sea.

INTRODUCTION

Anglerfish (*Lophius piscatorius* Linnaeus, 1758 and *Lophius budegassa* Spinola, 1807) are some of the target species of the Mediterranean multispecific trawl fishery (Bertrand *et al.*, 2000). They are distributed throughout the Mediterranean basin as well as in the eastern Atlantic (Fischer *et al.*, 1987). Both the Mediterranean *Lophius* species have a very similar colouration and their main distinguishing character is the colour of the peritoneum (pale in *L. piscatorius*, dark in *L. budegassa*). Both species have a wide bathymetric distribution, from shallow waters down to 1000 m depth. Information on the biology and ecology of Mediterranean *Lophius* species is scarce and only a few papers related to growth in this area are available (Tsimenides and Ondrias, 1980; Tsimenides, 1984). In the Atlantic Ocean, most studies on these species have dealt with age and growth, food and reproduction aspects (Crozier, 1985, 1989; Dupouy *et al.*, 1986; Pereda and Villamor, 1991; Afonso-

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Dias and Hislop, 1996; Quincoces *et al*., 1998a,b; Hislop *et al*., 2000, 2001).

The MEDITS research project allowed to collect, for the first time, a large dataset in a wide area of the Mediterranean Sea by means of trawl surveys (Bertrand *et al.*, 2000, 2002). This has contributed to the improvement of the study and knowledge of the demersal species at "large basin" level. In this paper, the occurrence and abundance patterns of the two species of *Lophius* occurring in the Mediterranean were analysed in the different geographic sampled areas. Demographic structures of the catches were also studied on a broad spatial scale in order to obtain patterns in spatio-temporal variation in population structure of *Lophius* species along the continental shelf and slope of the whole Mediterranean Sea. Some information on biological features is also reported.

MATERIAL AND METHODS

Biological samples were obtained from six spring-summer trawl surveys carried out from 1994 to 1999. The sampling region included a wide area of the Mediterranean Sea, from Alborán Sea in the west to the South Aegean Sea in the east, and it was divided in 40 sectors. Details of surveys design and methodology can be found in Bertrand *et al.* (2000, 2002). A total of 6336 valid hauls were undertaken during the MEDITS surveys (1994-1999).

With regard to the present paper, all *Lophius* specimens collected in the surveys were measured and sexed (maturity stages were also determined) following the common MEDITS protocol (Bertrand *et al*., 2000, 2002). Catch data (weight and number of collected specimens) were standardised to a trawled surface unit (km^2). The obtained data-set

TABLE 1. – *Lophius piscatorius*: mean biomass (kg/km^2) estimated from the MEDITS trawl surveys per depth stratum, geographical sector and year (1994-1999). Not sampled strata are indicated by '*'. Values higher than 50 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	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
112a	Alicante	0	3	0	0	0	0	7	0	0	0	0	1	0	7	0
113a	Catalan Sea	0	6	15	18	0	1	6	1	19	21	0	3	16	0	0
114a	W Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
114b	E Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
121a	W Gulf of Lions	0	3	0	14	33	5	18	4	**53**	27	0	31	12	4	40
121b	E Gulf of Lions	0	0	7	**54**	**51**	0	5	18	0	**72**	0	3	25	22	0
131a	NE Corsica	*	0	0	0	0	*	16	0	14	11	*	14	16	8	36
131b	SE Corsica	*	13	3	0	**93**	*	3	1	25	36	*	47	4	7	0
132a	N Ligurian Sea	0	0	**159**	0	7	3	4	15	14	11	0	1	0	0	0
132b	E Ligurian Sea	0	10	1	1	0	0	0	0	11	0	0	4	1	5	17
132c	N Tyrrhenian	0	3	13	0	7	0	0	0	0	9	0	0	0	6	13
132d	C Tyrrhenian	0	0	0	0	0	0	0	0	0	4	0	4	1	7	0
133a	SE Sardinia	0	1	0	0	0	1	5	0	2	0	0	21	0	0	**56**
133b	NE Sardinia	0	3	0	39	**70**	11	1	8	0	0	0	25	0	20	**67**
133c	N Sardinia	0	0	43	0	0	0	0	**51**	0	0	0	30	15	38	0
133d	NW Sardinia	32	15	0	0	0	*	4	6	0	0	10	23	6	5	31
133e	W Sardinia	0	*	0	0	0	0	0	0	0	0	0	31	0	0	0
133f	SW Sardinia	0	4	0	10	5	9	32	4	7	0	0	23	**57**	16	6
133g	S Sardinia	0	0	0	3	0	0	*	5	1	0	0	19	4	30	8
134a	SE Tyrrhenian	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0
134b	SW Tyrrhenian	0	5	0	0	0	0	13	0	0	0	0	0	0	0	0
134c	Sicilian Chan.	8	0	0	1	2	4	7	1	0	11	0	0	0	0	2
211a	N Adriatic Sea	3	5	*	*	*	0	0	*	*	*	1	0	*	*	*
211b	Central Adriatic	0	1	9	0	0	0	0	0	0	0	0	0	0	0	0
211c	N Adriatic-Slov	*	*	*	*	*	*	*	*	*	*	0	*	*	*	*
211d	NE Adri Croatia	*	*	*	*	*	*	*	*	*	*	0	1	0	0	*
221a	E Sicily	0	0	0	0	0	1	1	0	0	0	0	0	0	4	0
221b	NW Ionian Sea	0	2	0	0	0	5	4	0	0	0	0	0	0	0	0
221c	N Ionian Sea	0	0	3	0	0	13	5	2	0	0	0	0	0	0	0
221d	N Ionian Sea	*	0	0	1	0	0	0	4	0	0	11	0	0	0	0
221e	SW Adriatic	0	19	3	19	11	*	0	22	0	0	*	0	11	0	0
221f	SW Adriatic	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
221g	SW Adriatic	0	0	0	*	28	0	0	0	*	0	0	1	0	*	0
221h	SW Adriatic	0	0	11	9	**60**	0	0	0	**54**	43	0	1	0	45	0
221i	SE Adriatic	*	*	*	*	*	*	*	*	*	*	0	2	0	4	22
222a	E Ionian Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0
223a	Argosaronikos	0	**187**	4	0	0	2	0	47	15	0	0	0	31	42	0
224a	N Aegean Sea	4	12	12	17	5	0	0	6	1	0	13	4	9	29	0
225a	S Aegean Sea	0	0	2	4	1	0	0	0	0	7	0	0	0	5	0

was processed in order to compute biomass indices (kg/km^2) per year, geographical sectors and depth strata (10-50 m; 51-100 m; 101-200 m; 201-500 m; 501-800 m).

The spatial and temporal variation of the population demographic structure was studied from the length-frequency distributions by year, depth-strata (continental shelf: 0-200 m; continental slope: 201-800 m) and main geographic sectors. These areas were selected on the basis of the "old" GFCM divisions: Balearic Sea (37.1.1), Gulf of Lions (37.1.2), Thyrrenian Sea (37.1.3), Adriatic Sea (37.2.1), Ionian Sea (37.2.2) and Aegean Sea (37.3.1).

Length frequencies were calculated considering 5 cm size intervals. We applied correspondence analysis techniques to examine patterns of variation in the proportion of sizes in the samples (only samples >15 fish were considered). A global length distribution for each species, obtained from the overall MEDITS data set, with 2 cm size intervals, is also presented. The length frequency analysed data were obtained from the 1996-1999 surveys (reduced set). In the above mentioned period the Eastern Adriatic (Slovenia, Croatia and Albania), Morocco and Malta were included in the MEDITS Project, thus the grouping of length data from different sectors can be considered more effective (the chosen GFCM divisions were fully covered by MEDITS surveys).

Maturity stage data were analysed and used to fit a maturity curve by means of the logistic model (Saila *et al*., 1988). This elaboration was possible because the sampling period was comprised within the spawning period of *L. piscatorius* and *L. budegassa*, which takes place in spring-summer in the Mediterranean basin (Fischer *et al*., 1987). Maturity ogives were computed by using maturity-per-length

TABLE 1 (Cont.). – *Lophius piscatorius*: mean biomass (kg/km^2) estimated from the MEDITS trawl surveys per depth stratum, geographical sector and year (1994-1999). Not sampled strata are indicated by '*'. Values higher than 50 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	0	2	0	0	0	0	0	11	0	0	0	13	0	0	0
112a	Alicante	0	1	0	0	40	0	0	1	0	0	0	0	0	13	0
113a	Catalan Sea	0	2	3	15	0	0	4	9	0	0	0	1	0	6	0
114a	W Morocco	*	*	*	*	*	*	*	*	*	*	*	0	0	0	0
114b	E Morocco	*	*	*	*	*	*	*	*	*	*	*	0	0	0	0
121a	W Gulf of Lions	0	4	20	**72**	14	2	4	0	32	0	4	9	10	15	**74**
121b	E Gulf of Lions	0	0	6	**125**	0	0	1	11	**70**	**140**	6	5	21	**254**	*
131a	NE Corsica	*	0	*	0	35	*	0	0	0	**53**	*	2	0	14	0
131b	SE Corsica	*	0	0	44	*	*	0	0	0	0	*	8	0	0	**74**
132a	N Ligurian Sea	0	0	0	0	0	8	1	0	5	0	8	16	70	12	8
132b	E Ligurian Sea	0	6	9	0	13	0	18	0	9	9	0	0	0	0	0
132c	N Tyrrhenian	0	0	0	1	16	0	0	0	9	9	0	0	0	0	9
132d	C Tyrrhenian	0	0	0	4	0	0	0	0	0	0	0	0	0	1	8
133a	SE Sardinia	0	0	6	0	0	1	**58**	0	36	0	2	0	0	12	0
133b	NE Sardinia	0	19	32	10	0	0	5	1	17	2	10	0	1	0	0
133c	N Sardinia	0	16	0	0	0	0	0	0	0	0	0	8	9	23	0
133d	NW Sardinia	32	13	0	0	0	0	0	0	0	0	0	2	0	0	13
133e	W Sardinia	0	0	26	0	21	0	0	13	26	34	0	2	0	0	0
133f	SW Sardinia	0	15	0	1	8	0	1	2	7	26	22	0	12	21	41
133g	S Sardinia	0	5	6	29	29	0	1	0	10	7	6	14	9	0	**75**
134a	SE Tyrrhenian	0	0	43	3	3	0	0	8	3	6	0	3	0	0	0
134b	SW Tyrrhenian	0	5	3	4	0	0	3	3	2	0	0	2	0	0	0
134c	Sicilian Chan.	0	0	0	5	0	3	3	0	9	11	2	0	0	0	13
211a	N Adriatic Sea	0	0	*	*	*	0	4	*	*	*	2	3	*	*	*
211b	Central Adriatic	0	3	1	0	0	0	0	0	3	*	0	1	0	0	*
211c	N Adriatic-Slov	0	*	*	*	*	27	*	*	*	*	0	*	*	*	*
211d	NE Adri Croatia	0	2	1	0	*	5	0	0	0	*	*	*	*	*	*
221a	E Sicily	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
221b	NW Ionian Sea	1	0	0	0	0	0	2	0	0	0	0	1	0	0	5
221c	N Ionian Sea	0	0	2	0	0	1	0	0	0	0	1	1	1	0	0
221d	N Ionian Sea	6	0	0	8	0	0	0	22	0	0	0	0	0	0	0
221e	SW Adriatic	*	0	**101**	1	0	*	0	0	0	0	*	1	1	12	49
221f	SW Adriatic	0	0	0	0	0	0	0	0	0	0	0	3	4	0	0
221g	SW Adriatic	1	1	0	*	0	0	0	0	*	**273**	0	10	2	*	1
221h	SW Adriatic	0	1	0	15	0	0	0	0	29	33	0	2	2	0	0
221i	SE Adriatic	0	1	0	0	0	0	0	0	0	7	0	0	0	0	0
222a	E Ionian Sea	26	0	0	29	0	0	0	0	0	0	0	0	0	0	39
223a	Argosaronikos	8	0	**53**	0	0	0	0	27	0	0	0	0	0	0	0
224a	N Aegean Sea	0	0	7	33	7	0	0	0	8	16	0	0	0	40	0
225a	S Aegean Sea	0	0	24	16	0	0	0	0	2	2	0	0	0	13	0

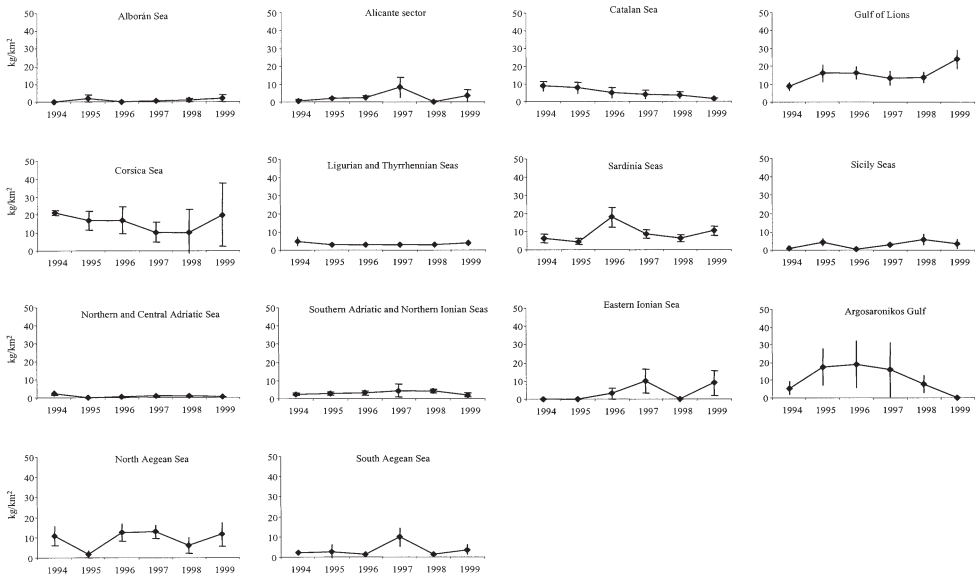


FIG. 1. – Trends of mean values (+/- standard deviation) of biomass indices of *Lophius piscatorius* per areas (aggregate sectors) during the investigated period (1994-1999).

TABLE 2. – *Lophius budegassa*: mean biomass (kg/km^2) estimated from the MEDITS trawl surveys per depth stratum, geographical sector and year (1994-1999). Not sampled strata are indicated by '*'. Values higher than 50 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	31	35	18	10	4	0	36	40	19	11	37	37	10	18	11
112a	Alicante	0	11	38	4	2	0	6	36	12	1	0	24	21	12	2
113a	Catalan Sea	1	13	**52**	19	0	0	18	36	9	0	0	11	16	11	0
114a	W Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
114b	E Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
121a	W Gulf of Lions	0	37	**116**	41	8	0	**67**	**152**	41	0	0	**95**	22	15	0
121b	E Gulf of Lions	0	9	**110**	14	0	0	52	**99**	15	9	0	**73**	**57**	**55**	18
131a	NE Corsica	*	44	19	36	0	*	26	8	13	0	*	0	0	1	0
131b	SE Corsica	*	0	0	0	0	*	0	0	0	0	*	0	0	0	0
132a	N Ligurian Sea	0	6	27	5	0	0	6	16	0	0	0	2	6	5	0
132b	E Ligurian Sea	0	3	16	5	5	0	3	19	5	0	0	14	33	15	0
132c	N Tyrrhenian	0	2	7	1	0	0	2	12	5	0	0	7	6	5	0
132d	C Tyrrhenian	0	5	5	0	0	0	0	2	1	5	0	0	0	0	0
133a	SE Sardinia	0	0	4	14	9	3	0	13	0	0	0	0	40	6	1
133b	NE Sardinia	0	9	0	16	0	0	13	0	4	0	0	0	0	12	0
133c	N Sardinia	0	0	41	5	5	0	0	0	36	0	0	0	12	6	0
133d	NW Sardinia	0	20	0	6	0	*	0	0	0	0	0	0	4	0	0
133e	W Sardinia	0	*	43	19	0	0	0	14	16	0	0	0	0	0	0
133f	SW Sardinia	0	20	31	17	3	0	0	4	13	2	0	0	12	10	1
133g	S Sardinia	0	0	2	11	1	0	*	0	2	0	0	0	2	8	0
134a	SE Tyrrhenian	1	0	2	3	0	0	0	0	2	0	0	0	1	2	0
134b	SW Tyrrhenian	0	20	26	9	0	15	41	48	2	1	1	34	12	1	0
134c	Sicilian Chan.	0	8	2	6	2	0	0	1	3	5	0	0	1	5	1
211a	N Adriatic Sea	0	14	*	*	*	3	9	*	*	*	4	4	*	*	*
211b	Central Adriatic	0	12	3	1	0	0	1	1	0	0	0	5	6	0	0
211c	N Adriatic-Slov	*	*	*	*	*	*	*	*	*	*	0	*	*	*	*
211d	NE Adri Croatia	*	*	*	*	*	*	*	*	*	*	0	20	19	19	*
221a	E Sicily	0	0	2	1	0	0	0	10	0	0	0	0	0	1	0
221b	NW Ionian Sea	0	0	0	0	3	0	2	4	1	3	1	19	0	0	0
221c	N Ionian Sea	0	0	9	1	0	0	0	0	1	0	0	1	2	2	0
221d	N Ionian Sea	*	0	**53**	2	0	0	12	**116**	1	0	7	6	**62**	1	0
221e	SW Adriatic	0	1	**61**	8	3	*	2	36	6	0	*	10	20	6	0
221f	SW Adriatic	0	3	3	0	0	0	0	3	0	0	0	1	6	0	0
221g	SW Adriatic	0	1	5	*	0	0	0	0	*	0	0	1	6	*	0
221h	SW Adriatic	1	2	12	14	1	0	0	4	1	3	0	0	4	32	0
221i	SE Adriatic	*	*	*	*	*	*	*	*	*	*	9	11	8	8	0
222a	E Ionian Sea	0	12	7	18	0	0	0	**53**	3	0	0	29	**139**	**55**	0
223a	Argosaronikos	0	**174**	**112**	28	0	0	**136**	**85**	11	0	2	**106**	41	40	15
224a	N Aegean Sea	30	**76**	**70**	9	8	0	**72**	12	7	2	**100**	**97**	19	12	2
225a	S Aegean Sea	0	**89**	**166**	**66**	7	0	18	**102**	**61**	9	0	35	**75**	44	2

percentages. Maturity stages I and II, according to the MEDITS protocol (Bertrand *et al*., 2000) were considered "not mature", while individuals staged III and IV were considered respectively "mature" and "after spawning". Only female specimens were analysed, because of data availability and quality.

RESULTS

Distribution and abundance

Lophius piscatorius was caught on 957 hauls out of the 6336 valid hauls undertaken during the MEDITS cruises (overall occurrence: 15%). Frequency of occurrence was higher on shelf bottoms (17%) than on slope bottoms (12%). High differences in mean biomass (kg/km^2) were obtained by sector, depth-strata and year (Table 1). The highest biomass indices were found on the slope in the Gulf of Lions (Fig. 1). In Corsica and Argosaronikos Gulf sectors, high average values, but with high deviation, were also obtained.

Lophius budegassa was caught on 2401 hauls (overall occurrence: 38%). The species was found with similar frequency on shelf bottoms (39%) and on the slope (37%). High differences in mean biomass (kg/km^2) were also obtained by sector, depth-strata and year (Table 2). The highest biomass indices were mostly found on the shelf of the Gulf of Lions, Argosaronikos Gulf and North and South Aegean Seas (Fig. 2).

Stock demography

Lophius piscatorius individuals ranged between 1 and 100 cm in length (Fig. 3). Differences in

TABLE 2 (Cont.). – *Lophius budegassa*: mean biomass (kg/km^2) estimated from the MEDITS trawl surveys per depth stratum, geographical sector and year (1994-1999). Not sampled strata are indicated by '*'. Values higher than 50 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	**106**	17	4	28	36	9	38	12	12	7	14	2	0	3	4
112a	Alicante	0	42	28	13	2	0	7	10	11	0	0	1	3	0	0
113a	Catalan Sea	0	13	**55**	17	0	0	5	38	0	0	2	7	15	2	0
114a	W Morocco	*	*	*	*	*	*	*	*	*	*	*	0	6	**69**	44
114b	E Morocco	*	*	*	*	*	*	*	*	*	*	*	0	5	36	2
121a	W Gulf of Lions	16	**56**	14	11	0	0	25	4	28	0	1	40	17	16	10
121b	E Gulf of Lions	2	30	41	34	0	0	8	**59**	2	0	0	14	**102**	18	*
131a	NE Corsica	*	30	*	11	0	*	0	27	4	0	*	0	0	3	0
131b	SE Corsica	*	0	8	2	*	*	0	48	1	0	*	0	0	6	0
132a	N Ligurian Sea	6	11	3	0	0	0	0	1	8	0	15	0	8	7	0
132b	E Ligurian Sea	0	7	24	10	0	0	1	19	7	0	0	1	24	7	7
132c	N Tyrrhenian	0	0	7	9	0	0	0	5	2	0	0	0	17	3	0
132d	C Tyrrhenian	0	0	6	1	0	0	0	5	0	0	0	0	0	0	0
133a	SE Sardinia	0	0	18	9	5	0	**58**	8	5	0	1	0	15	1	5
133b	NE Sardinia	0	5	0	2	0	0	16	0	16	0	0	0	0	7	0
133c	N Sardinia	0	0	21	6	0	0	0	39	35	0	0	0	16	7	0
133d	NW Sardinia	0	**68**	16	0	0	0	0	8	0	0	0	0	0	**58**	0
133e	W Sardinia	0	0	17	5	0	0	0	25	0	0	0	0	20	0	0
133f	SW Sardinia	0	0	20	23	0	0	0	16	21	0	0	17	25	11	2
133g	S Sardinia	3	19	0	7	0	0	0	35	8	0	0	0	0	0	0
134a	SE Tyrrhenian	0	1	2	3	2	0	1	4	2	0	0	0	2	1	0
134b	SW Tyrrhenian	0	0	0	0	0	0	0	0	2	0	1	6	3	3	0
134c	Sicilian Chan.	0	0	0	2	1	0	1	0	14	5	0	0	0	2	0
211a	N Adriatic Sea	0	0	*	*	*	0	0	*	*	*	0	2	*	*	*
211b	Central Adriatic	0	3	1	12	2	0	1	2	1	*	0	6	5	7	*
211c	N Adriatic-Slov	0	*	*	*	*	0	*	*	*	*	0	*	*	*	*
211d	NE Adri Croatia	4	11	17	13	*	10	13	9	2	*	*	*	*	*	*
221a	E Sicily	0	2	2	0	0	0	4	3	0	0	1	1	5	1	0
221b	NW Ionian Sea	0	3	4	4	1	0	34	0	2	2	11	4	26	0	0
221c	N Ionian Sea	1	5	0	0	0	0	9	0	2	0	1	2	1	1	0
221d	N Ionian Sea	0	0	9	0	0	0	2	35	2	0	0	0	6	2	0
221e	SW Adriatic	*	0	27	3	0	*	5	29	1	0	*	3	22	6	5
221f	SW Adriatic	0	2	4	0	0	0	4	4	6	0	0	7	13	5	0
221g	SW Adriatic	0	0	0	*	0	0	6	2	*	0	0	0	2	*	0
221h	SW Adriatic	0	0	1	7	10	0	1	2	2	7	0	2	8	7	13
221i	SE Adriatic	0	15	10	5	0	10	22	0	0	0	0	15	11	7	2
222a	E Ionian Sea	38	15	26	41	4	4	16	19	10	1	36	26	24	16	4
223a	Argosaronikos	38	48	**53**	39	3	**66**	44	29	13	**68**	**72**	28	**56**	10	36
224a	N Aegean Sea	**68**	**79**	25	17	12	30	27	17	14	17	39	**58**	13	10	2
225a	S Aegean Sea	0	19	**76**	25	14	0	36	44	23	11	0	19	20	33	12

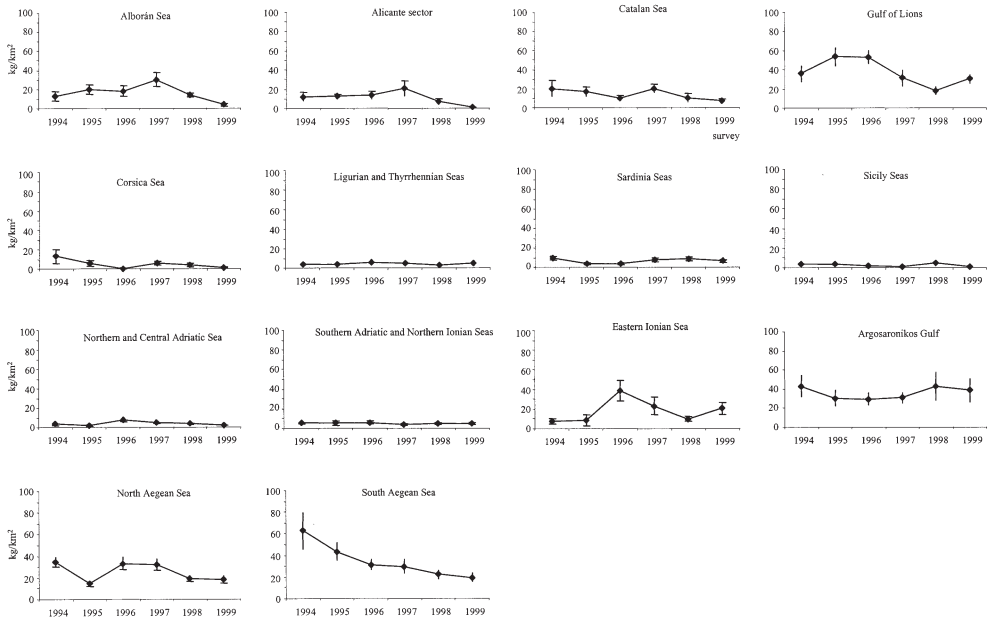


FIG. 2. – Trends of mean values (+/- standard deviation) of biomass indices of *Lophius budegassa* per areas (aggregate sectors) during the investigated period (1994-1999).

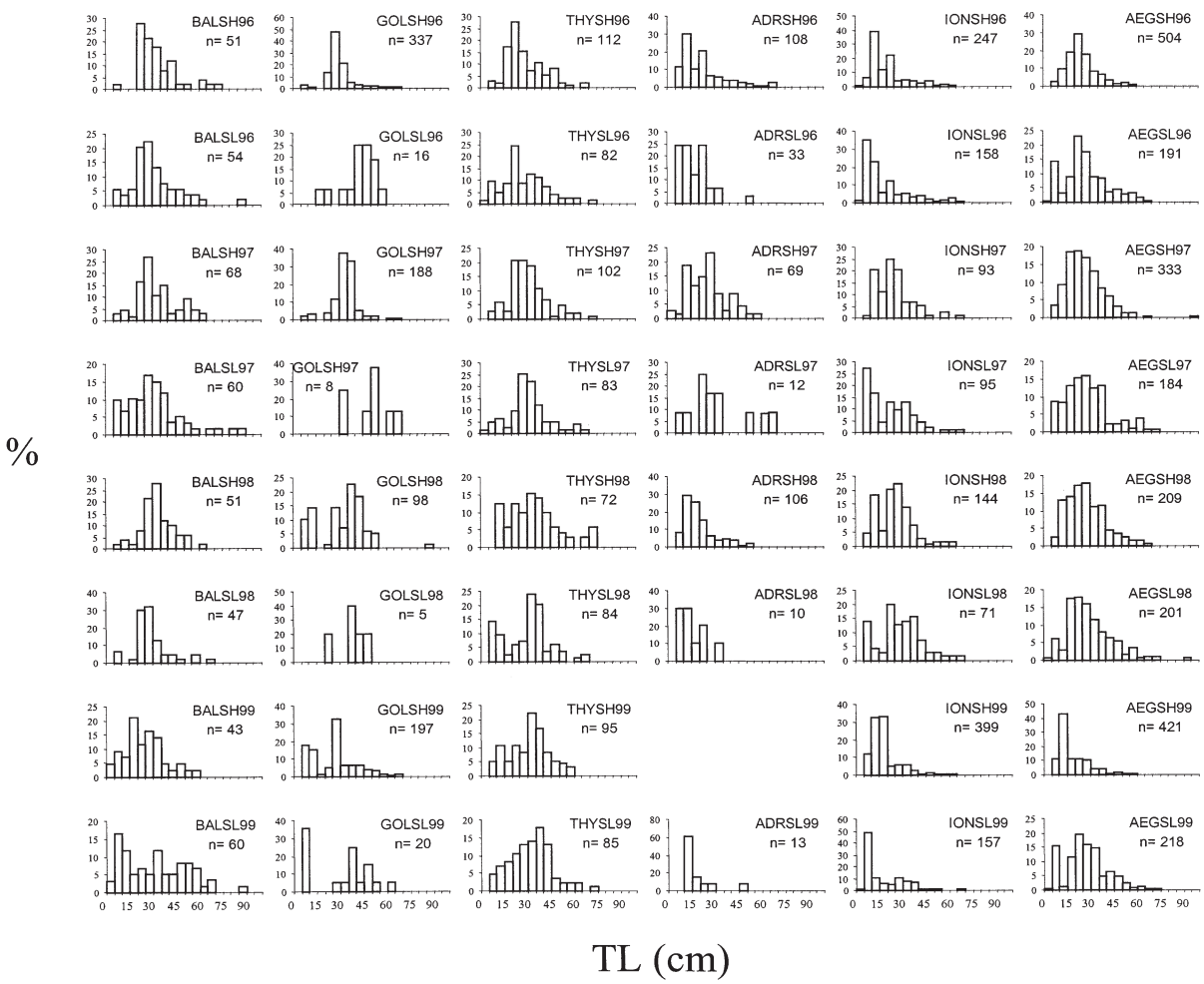


FIG. 3. – Length-frequency distributions of *Lophius piscatorius* by sector (BAL: Balearic; GOL: Gulf of Lions; THY: Thyrrenian; ADR: Adriatic; ION: Ionian; AEG: Aegean), depth-strata (SH: continental shelf, 0-200 m; SL: continental slope, 201-800 m) and year (96: 1996, 97: 1997, 98: 1998 and 99: 1999).

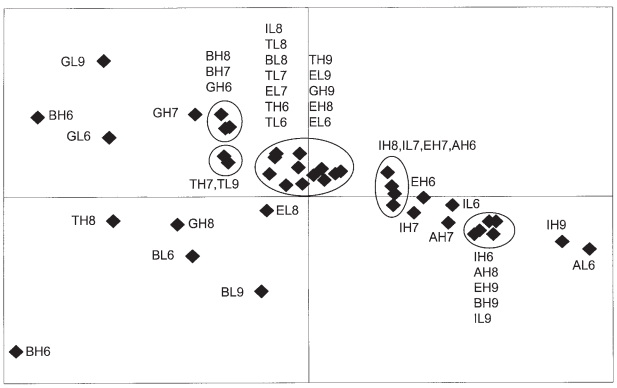


FIG. 4. – Correspondence analysis between length-frequency samples of *Lophius piscatorius* obtained by sector (B: Balearic; G: Gulf of Lions; T: Thyrrenian; A. Adriatic; I: Ionian; E: Aegean), depth-strata (H: continental shelf, 0-200 m; L: continental slope, 201-800 m) and year (6: 1996; 7: 1997; 8: 1998; 9: 1999).

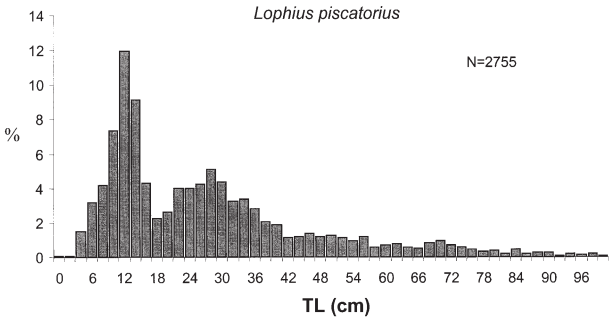


FIG. 5. – Overall length frequency distribution of *Lophius piscatorius* in the Mediterranean from MEDITS 1994-1999 trawl surveys.

length-frequency distributions have been studied with correspondence analysis. The two first factorial axes of the correspondence analysis (Fig. 4) explained 52% of the total variability of data (40% for the first axes and 12% for the second). The first axis discriminated assemblages from the continental shelf, with predominance of specimens smaller than 30-40 cm, from the continental slope, in which the specimens larger than 50 cm constituted an important fraction. No discrimination between geographic areas was observed.

The overall length frequency distribution obtained from the MEDITS data set is shown in Figure 5. Different modes could be detected, the most

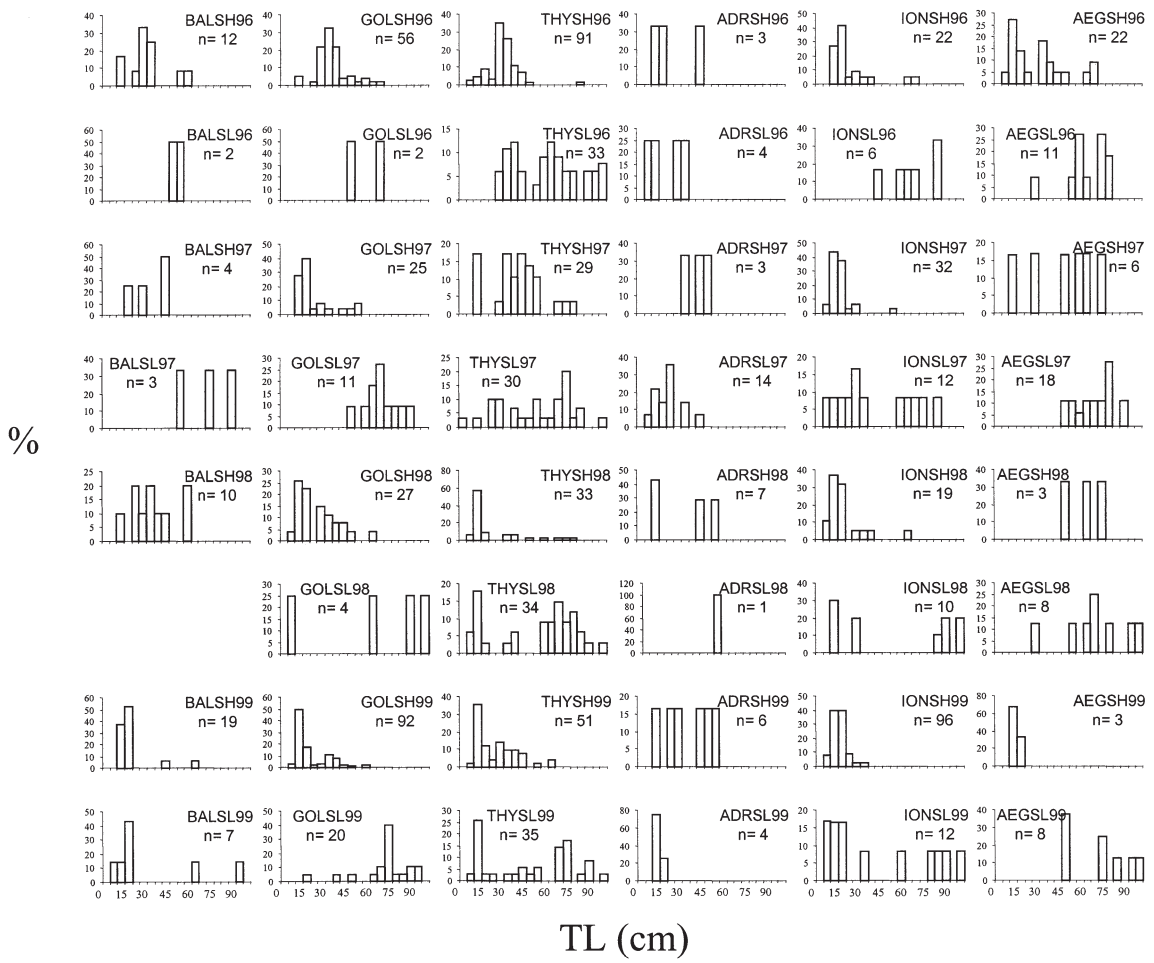


FIG. 6. – Length-frequency distributions of *Lophius budegassa* by sector, depth-strata and year. See abbreviations in Figure 3.

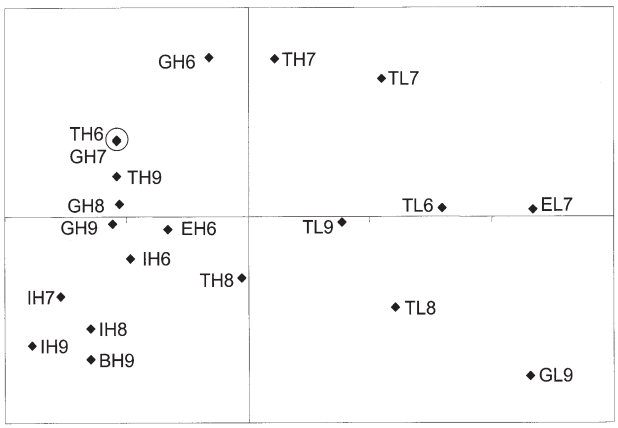


FIG. 7. – Correspondence analysis between length-frequency samples of *Lophius budegassa* obtained by sector, depth-strata and year. See abbreviations in Figure 4

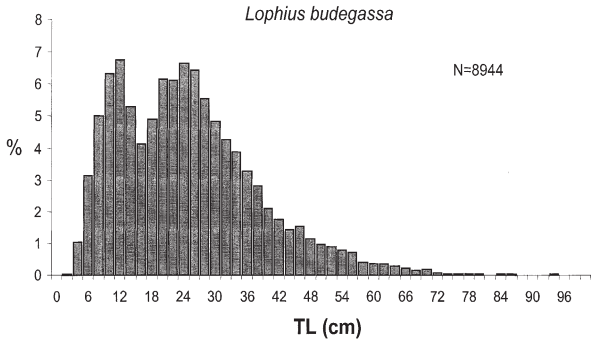
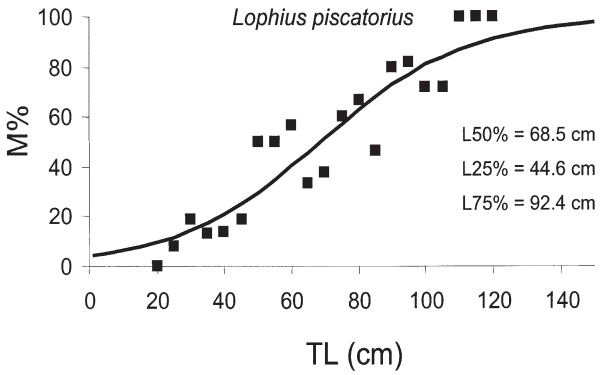


FIG. 8. – Overall length frequency distribution of *Lophius budegassa* in the Mediterranean from MEDITS 1994-1999 trawl surveys.

important of which were found between 12-16 cm and around 30 cm TL.

Lophius budegassa ranged between 1 and 95 cm in length, with a clear predominance of specimens smaller than 40-60 cm (Fig. 6). The two first factorial axes of the correspondence analysis (Fig. 7) explained 45% of the total variability of data (30% for the first axis and 15% for the second). The first axis discriminated assemblages from central and eastern Mediterranean (Adriatic, Ionian and Aegean Seas), with clear modes of specimens smaller than 30 cm, from western Mediterranean (Balearic and Thyrrenian Seas and Gulf of Lions) assemblages, which also showed modes at around 30 mm and larger sizes. No discrimination between continental shelf and slope assemblages was observed.

The length frequency distribution obtained from the overall MEDITS data set is shown in Fig. 8. Two main modes could be detected, the first at 12-14 cm TL and the other between 22 and 28 cm.



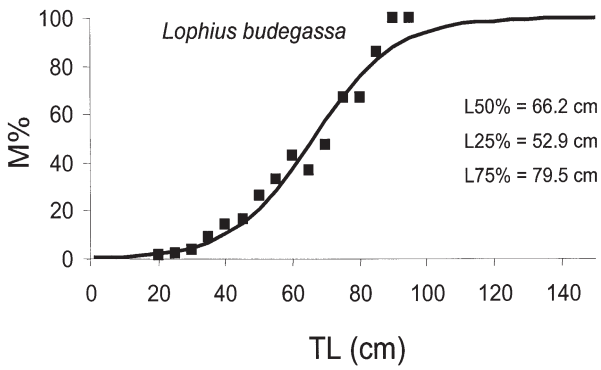


FIG. 9. – *Lophius piscatorius* and *Lophius budegassa*: maturity curves of female specimens in the Mediterranean estimated from MEDITS 1994-1999 trawl surveys data.

Size at maturity

Logistic curves resulting from data processing are shown in Figure 9. $L_{50\%}$ was 68.5 cm ($L_{25\%}$ = 44.6 cm; $L_{75\%}$ = 92.4 cm) and 66.2 cm ($L_{25\%}$ = 52.9 cm ; $L_{75\%}$ = 79.5 cm) total length for *L. piscatorius* and *L. budegassa*, respectively.

DISCUSSION

The analysis of the occurrence and distribution of *L. piscatorius* and *L. budegassa* in a wide area of the Mediterranean Sea adds some information on the ecology of these species. Concerning the frequency of occurrence, *L. budegassa* presented higher degree of occurrence (38%) than *L. piscatorius* (15%) in trawl catches, in accordance with the findings of Tsimenides and Ondrias (1980).

The distribution of the biomass evidenced some geographical differences. Both *Lophius* species showed high biomass indices in the eastern Mediterranean Sea and in the northwestern Mediterranean sectors, while much lower values were reported for

the Central Mediterranean. No clear trend was evident from the short time-series available, except for the South Aegean Sea where *L. budegassa* biomass strongly decreased.

Taking into account the length at first maturity obtained for *Lophius* species, the length composition obtained along the whole European Mediterranean, showed that the exploited *Lophius budegassa* populations mainly consist of immature specimens. This is a general rule of demersal species exploited with small-meshed bottom trawls in the area (Caddy, 1993). In contrast, the proportion of mature specimens of *Lophius piscatorius* was more important.

The analysis of length-frequency structures of both species showed clear differences, which can be attributed to different factors. A geographic gradient is observed in size composition of *Lophius budegassa* populations, with discrimination between eastern and central areas, where the smallest specimens (<30 cm) are well represented, and the western part of the Mediterranean, where the smallest modes are at around 30-40 cm in length. A wide variety of factors could be on the basis of these differences, from distinct environmental conditions (e.g. oceanography and bottom topography) to different levels of fishing exploitation along the whole Mediterranean area.

By contrast, size composition of *Lophius piscatorius* populations seems to be affected by bathymetry, but not by geographic factors. In this species, clear differences between continental shelf and slope assemblages have been observed, with predominance of small and large specimens, respectively. This can be explained by an ontogenetic migration of the species along the bathymetric gradient, a common phenomenon for other deep-sea fish in the Mediterranean (e.g. Macpherson and Duarte, 1991). Moreover, *L. piscatorius* in the North Sea spawns in deep water and the transition from the pelagic to the demersal phase takes place in relatively shallow water (Hislop *et al*., 2001).

With regard to biological features, size frequency distributions at regional and Mediterranean level give some information on age cohorts. First cohorts are well defined, and they could be used to validate referenced information on the growth of the species in the Mediterranean (Tsimenides and Ondrias, 1980; Tsimenides, 1984).

The reported maturity curves have to be considered as a first attempt to identify sexual maturity lengths for *L. piscatorius* and *L. budegassa* in the Mediterranean. The $L_{50\%}$ values estimated for females of both species are comparable with East Atlantic results (Afonso-Diaz and Hislop, 1996; Quincoces *et al*., 1998a,b) and correspond to around 3-4 years for *L. piscatorius* and more than 4 years for *L. budegassa* in the Mediterranean (Tsimenides and Ondrias, 1980).

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