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Geographical and bathymetric distribution of silver scabbardfish *Lepidopus caudatus* in North Aegean Sea

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Abstract

A study on silver scabbardfish *(Lepidopus caudatus)* distribution and demographic structure was carried out in northern Aegean Sea from bottom trawl surveys (MEDITS: Mediterranean International Bottom Trawl Survey) during1996-2006. The surveys were performed each year (except in 2002) between June and July. Approximately 65 hauls were carried out in total, at depth range between 10 and 800 m. The sampling design adopted was random-stratified including five depth zones: 10-50, 50-100, 100-200, 200-500 and 500-800 m. Data of biomass (kg/km^2) and abundance (N/km^2) were investigated in order to describe the geographical and bathymetric distribution. Scabbardfish was more frequently found in the area of Lesvos Island between depths of 340 and 370 m. The hotspots of scabbardfish biomass coincided with the longitudinal thermal front that is generated between the eastern (colder) and the western (warmer) surface water masses during the summer months. The aim of this research was to analyze the distribution and demographic structure of *L. caudatus* and the associated species assemblages in the northern Aegean Sea.

Keywords: Fish bathymetric distribution, Fish geographic distribution, *Lepidopus caudatus*, Aegean Sea

Introduction

The silver scabbardfish, *Lepidopus caudatus*, is widely distributed worldwide throughout temperate seas of the world. Its presence has been recorded across the entire Mediterranean Sea (Bello and Rizzi 1988; Matarrese et al. 1996). It is a benthopelagic species inhabiting the continental shelf and upper slope. During the winter it is more abundant between 100 and 400 m, while during the summer scabbardfish lives in deeper waters (Nakamura and Parin 1993; Demestre et al. 1993; D'Onghia et al. 2000). Moreover, *L. caudatus* may be occasionally found in shallow inshore waters (Demestre et al. 1993; Nakamura and Parin 1993; Carbonara et al. 1999) or in superficial upwelled waters (Nakamura and Parin 1993). *L. caudatus* is normally caught by bottom-trawl net and long-lines and it is an important commercial fish species in the north eastern Atlantic and off Namibia and New Zealand (Barange et al. 1993; Nakamura and Parin 1993).

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In the Mediterranean Sea, the commercial exploitation of the silver scabbardfish is limited to Italy, Spain, Albania and Tunisia (Rosa et al. 2006) where only larger specimens reach a commercial value (Demestre et al. 1993; D'onghia et al. 2000). In Greek waters, *L. caudatus* is discarded species that is caught with other commercially important target species such as the European hake *Merluccius merluccius* (Tzanatos et al. 2007). Biology and exploitation of *L. caudatus* in the Mediterranean Sea have been studied in the northwest Mediterranean Sea (Orsi Relini et al. 1989; Demestre et al. 1993), in the Ionian Sea (D'onghia et al. 2000) and in the North Aegean Sea (Filiz and Bilge 2004).

The aim of the present study was to analyze of the distribution and demographic structure of *Lepidopus caudatus* and the associated species assemblages, in the northern Aegean Sea.

Materials and methods

Fish samples were obtained during ten bottom trawl surveys (MEDITS: Mediterranean International Bottom Trawl Survey) carried out in North Aegean Sea between 1996 and 2006 (Figure 1). The surveys were performed each year (except in 2002) between June and July using a standard net GOC 37 with a cod-end mesh opening of 20 mm (Bertrand 1994). Approximately 65 hauls were annually carried out, at a depth range between 10 and 800 m. The sampling design adopted was random-stratified including five depth zones: 10-50, 50-100, 100-200, 200-500 and 500-800m (Bertrand 1994). The number of hauls per depth stratum was determined according to the surface of each sub-area and the depth stratum. Hauls were carried out during the daylight.

The standard fishing speed was 3 knots on the ground and the haul duration was set at 30 min at depth less than 200 m and 60 min at depth more than 200 m. The fishing methods and vessels used were the same in all the MEDITS surveys. This study was based only on the hauls where the silver scabbardfish was caught. During each haul, catches were identified to the species level and the total number of fish and their weights were recorded. Furthermore, depth and water temperature from surface to bottom were recorded at the end of fishing by mean of a minilogger probe. Catch rates of silver scabbardfish and other species were calculated as catch weight (Kg), number (N)/(distance towed * horizontal opening net).

Biomass (kg/km^2) and abundance (N/km^2) were used to describe the geographic and bathymetric distribution of the species. ANOVA was used for elaboration of biomass data, while Principal Component Analysis (PCA) was used to describe the associated species assemblage. PCA analysis was performed on the matrix of log transformed biomass values of the most frequent species caught with silver scabbardfish. The hauls were considered as discriminators. Biplot graph (Fromentin and Fontaneau 2001) was used in order to represent the results of the PCA analysis. Calculations were carried out using the biplot and singular value decomposition macros for Excel (Lipkovich and Smith 2002). The relationship between silver scabbardfish biomass and abiotic factors (sea surface temperature, bottom temperature, depth, latitude, and longitude of each haul) was analyzed by multiple regression analysis considering the biomass as the dependent variable.

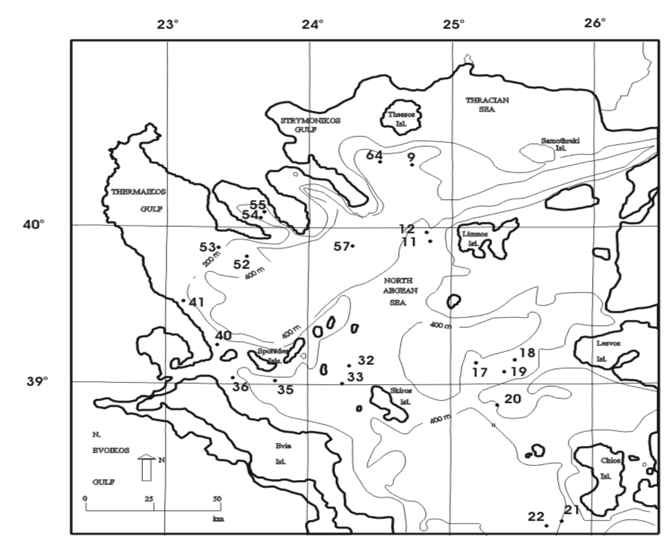

Fig. 1. Sampling stations

Results

The geographical distribution of fishing stations is shown in Figure 1. During the ten trawl surveys carried out between 1996 and 2006, *L. caudatus* was caught 104 times and was found in 22 of 65 planned hauls (Table 1).

Table 1. Hauls temporal distribution during the considered period (1996 – 2006)*

YEAR	Month	Day	Haul	N.M.	LT Min	LT Max	LT Mean	SD	S.S.W	T.C.W.
1996	6	25	11	2	140	500	320	254.6	1.62	1.62
	6	29	18	32	265	1430	514.5	297.6	4.89	6.23
	6	30	19	36	210	865	459.2	195.5	3.54	3.54
	7	12	32	45	615	1610	971.9	232.6	30.35	41.7
	7	13	35	1			595		0.15	0.15
	7	2	22	13	820	1440	1069.6	208.3	9.8	9.8
	7	2	27	4	745	1300	896.3	269.7	1.62	1.62
	7	22	53	5	1240	1445	1329	78.5	9.7	9.7
	7	23	55	5	645	1210	1024	241.6	3.75	3.8
	7	29	64	1			695		0.14	0.14
	7	8	29	1			735		0.18	0.18
1997	6	19	18	1			1330		1.1	1.1
	6	19	19	18	260	1310	604.4	276.6	4.3	4.3
	6	20	27	2	540	760	650	155.6	0.55	0.55
	6	21	21	1			1220		1.3	1.3
	6	24	22	4	245	1185	907.5	446.6	2.85	2.8
	6	27	33	6	590	760	639.2	70.5	1.52	1.52
	6	28	32	3	585	785	693.3	101	0.75	0.75
	6	29	35	1			415		0.07	0.07
	7	14	64	2	310	350	330	28.3	0.05	0.05
	7	3	41	21	280	495	399.8	55.8	2.2	5.9
	7	9	52	13	610	900	788.8	75	5.35	5.35
	7	9	53	7	595	695	648.6	35.3	1.4	1.4
1998	6	22	11	4	710	765	737.5	26.6	1.18	1.18
	6	22	12	1			650		0.2	0.2
	6	24	17	1			1145		0.95	0.95
	6	25	18	38	245	1110	595.5	247.5	7.8	8.1
	6	25	19	31	265	775	415.5	127.7	2	9.5
	6	30	21	1			735		0.3	0.3
	6	30	22	40	480	1100	726.5	111.6	12.6	12.6
	7	11	40	7	110	815	665.7	248.3	2.75	2.75
	7	14	53	2	635	710	672.5	53	0.38	0.38
	7	15	52	13	610	870	783.5	70.8	4.6	4.6
	7	16	54	1			1110		0.4	0.4
	7	2	27	5	685	1185	858	195.1	2.5	2.5
	7	3	29	1			380		0.04	0.04
	7	3	33	1			790		0.34	0.34
	7	4	32	1			510		0.07	0.07
	7	6	35	1			350		0.04	0.04
1999	6	19	9	1			550		0.15	0.15
	6	25	11	16	630	830	744.7	57.5	0.6	0.6
	6	29	17	33	680	925	785	65.4	13.5	13.5
	6	30	19	39	315	1025	649.2	232	10	47
	6	31	18	38	280	1230	670	283.5	12	78
	7	10	35	1			390		0.03	0.03
	7	11	36	2	430	440	435	7.1	0.08	0.08
	7	14	40	2	410	970	690	396	0.63	0.63
	7	16	52	9	530	925	768.9	119.9	2.9	2.9
	7	17	53	1			735		0.25	0.25
	7	23	57	1			730		0.28	0.28
	7	3	22	3	750	1270	948.3	281.1	1.8	1.8
	7	4	27	3	890	1295	1046.7	217.5	2.5	2.5
	7	7	29	1			735		0.3	0.3
	7	7	33	8	690	840	733.1	551.5	2.2	2.2
	7	9	32	1			460		0.04	0.04
2000	6	26	11	11	480	720	527.7	67.1	1.6	1.6
	6	30	17	2	835	960	897.5	88.4	1.06	1.06
	7	11	32	2	705	870	787.5	116.7	0.7	0.7
	7	16	40	4	410	675	487.5	126.8	0.34	0.34
	7	22	52	4	790	1050	871.3	121	2	2
	7	4	21	1			1200		1	1
	7	4	22	1			800		0.4	0.4

Table 1. Continued

YEAR	Month	Day	Haul	N.M.	LT Min	LT Max	LT Mean	SD	S.S.W	T.C.W.
2000	7	5	18	40	210	1100	817.5	238.1	19.4	19.4
	7	5	19	12	410	1025	807.9	199.3	4.8	4.8
	7	8	27	17	665	1080	761.8	114.9	5.9	5.9
	7	9	33	1			635		0.19	0.19
2001	6	11	17	9	710	1000	880.6	83.9	4.1	4.1
	6	12	18	40	225	1210	670.5	330.5	15.3	34.3
	6	12	19	65	225	1210	680.2	333.9	29.9	71.9
	6	18	22	6	720	1240	948.5	207.2	4.1	4.1
	6	22	29	17	340	490	398.5	47.1	0.9	0.9
	6	22	33	3	390	795	613.3	205.7	0.6	0.6
	6	23	32	4	685	805	755	51.8	1.68	1.68
	6	24	35	1			520		0.12	0.12
	6	9	11	10	640	745	692.5	29.2	3.2	3.2
2003	7	16	17	6	332	946	664	249.5	2	2
	7	17	18	69	338	669	542.5	70.8	6	6
	7	17	19	11	570	1010	652.8	144.3	0.18	1.85
	7	28	32	2	820	825	822.5	3.5	0.6	0.6
	7	30	57	5	455	622	563.4	68.3	0.55	0.55
2004	6	25	11	50	312	547	445	36.5	2.35	11
	6	25	32	1			820		0.42	0.42
	6	29	17	2	836	996	916	113.1	1.2	1.2
	7	1	18	64	290	1122	508.2	211.5	10	10
	7	1	19	100	297	1180	518.9	219.1	14.2	117
	7	13	22	1			813		0.32	0.32
	7	13	33	20	290	994	599.7	233.5	3.88	3.88
	7	18	40	5	416	430	423	5.1	0.2	0.2
	7	24	52	3	461	504	485	21.9	0.15	0.15
	7	24	53	1			468		0.12	0.12
	7	24	55	1			552		0.1	0.1
2005	6	22	18	50	232	1012	500.4	254.9	6.4	30.5
	6	22	19	50	280	440	362.1	41.4	1.56	10
	6	30	22	1			745		0.3	0.3
	7	1	27	2	417	749	583	234.8	0.4	0.4
	7	16	54	1			441		0.05	0.05
	7	2	29	3	700	1140	853.3	248.5	2.17	2.17
	7	2	33	2	728	810	769	58	0.57	0.57
	7	4	32	9	705	820	765	38	3.05	3.05
2006	6	11	11	5	713	780	735	28.3	1.32	1.32
	6	15	18	15	225	902	661.9	150.7	3.3	3.3
	6	15	19	6	415	869	611.7	209.5	1.32	1.32
	7	15	29	2	757	935	846	125.9	0.58	0.58
	7	15	33	2	705	717	712.3	6.4	0.8	0.8
All samples				1271	110	1610	627.8	258.5		

*Date: Year, Month, Day; N.M. = number of measured fish; LT Min = Minimum total length (mm); LT Max = Maximum total length (mm); LT Mean = Mean total length (mm); SD = Standard deviation; S.S.W = Sub Sample Weight; T.C.W. = Total Catch Weight.

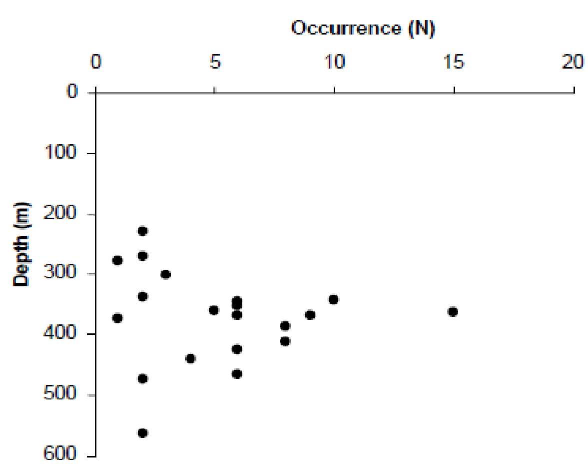

Fig. 2. Number (N) of hauls where *L. caudatus* was found according to trawl depth

Table 2. Hauls location and mean trawl depth

Hauls	Mean trawl depth (m)	Latitude	Longitude
9	354	40:29':13''	24:52':44"
11	344	40:02':68''	24:48':26"
12	565	40:04':29''	24:47':33"
17	465	39:08':12''	25:03':42"
18	343	39:07':68''	25:18':28"
19	363	39:05':43''	25:15':17"
21	302	38:11':44''	25:35':30"
22	385	38:10':20''	25:33':71"
27	426	38:45':74''	25:03':92"
29	368	38:52':44''	24:06':25"
32	367	39:08':28''	24:14':54"
33	411	38:57':17''	24:08':72"
35	354	39:02':19''	23:45':87"
36	374	39:03':08''	23:25':64"
40	441	39:18':01''	23:29':50"
41	278	39:31':30''	23:10':54"
52	363	39:50':71''	23:31':42"
53	361	39:51':59''	23:25':98"
54	270	40:02':07''	23:38':82"
55	558	40:05':23''	23:38':44"
57	474	40:01':66''	24:10':87"
64	338	40:31':55''	24:24':66"

L. caudatus was caught at depths between 228 and 565 m, more frequently between 300 and 400 m. Maximal frequency of hauls occurred during 1998 and 1999 and decreased afterward until 2003 (Table 2; Figure 2). During 2004, a second peak of scabbardfish occurrence was found while its occurrence substantially decreased between years 2005 and 2006. Although the species was widely distributed in the deep sea waters (200-600 m), however, it was more frequently found at west of the Lesvos Island (central North Aegean Sea) between depths of 340 and 370 m (Figure 3).

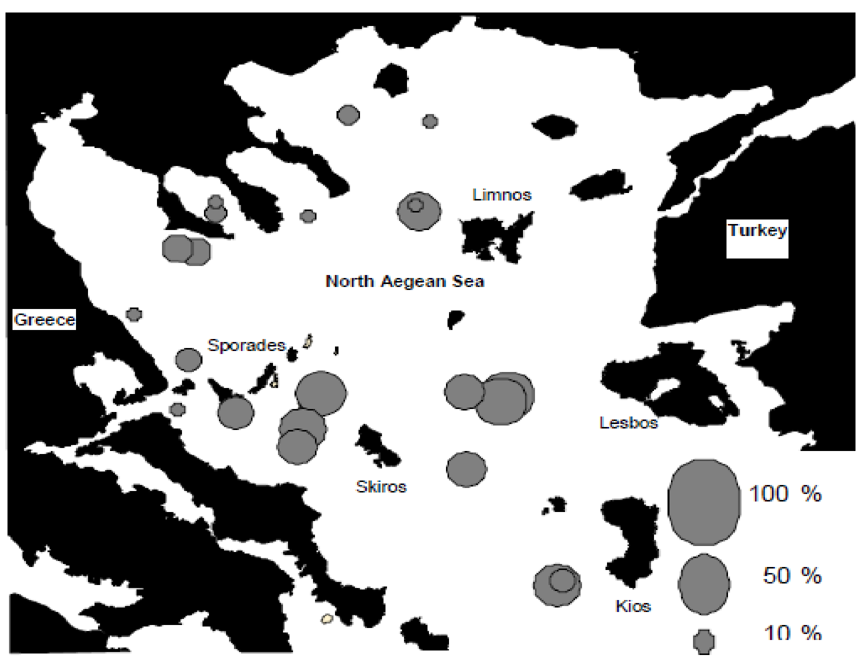

Fig. 3. Occurrence of *L. caudatus* for a ten-years period of trawl surveys in the North Aegean Sea

The scabbardfish biomass per haul ranged between 0.1 and 75%, but mainly between 0 and 10% of total (*L. caudatus* was found in 77% of hauls). Fish biomass was significantly higher (ANOVA, $P < 0.05$) in the depth strata between 301 and 400 m (Figure 4).

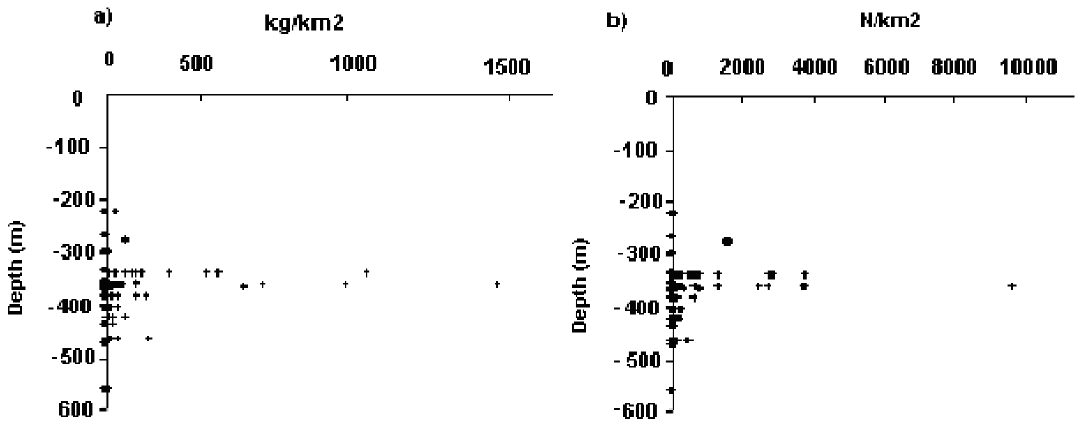

Fig. 4. Relation between fish biomass and depth

Higher biomass values were found in the area located to the west of the Lesvos Island at depths between 340 and 370 m (Figure 6). The species most frequently found in association with *L. caudatus* were, in decreasing order, *Lepidorombus boscii*, *Merluccius merluccius*, *Phycis blennoides*, *Parapenaeus longirostris*, *Argentina sphyraena*, *Lophius budegassa*, *Coelorhynchus coelorhynchus*, *Illex coindetii*, *Gadiculus argenteus*, *Scyliorhinus canicula*, *Hymenocephalus italicus*, *Chlorophtalmus agassizii*, and *Nephrops norvegicus*. PCA results (Figure 5) showed that the species assemblage composition was mainly influenced by the geographical location, while depth or time of sampling did not show any significant effect.

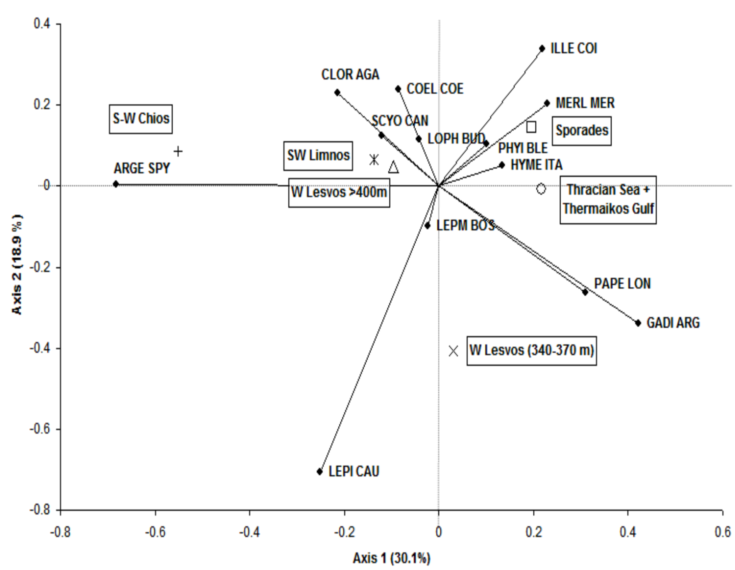

Fig. 5. Biplot representation of the survey areas and species assemblage (standardized and log-transformed biomass indices). Legend: ARGE SPY = *Argentina sphyraena*; CLOR AGA = *Chlorophtalmus agassizii*; SCYO CAN = *Scyliorhinus canicula*; LOPH BLUD = *Lophius budegassa*; LEPM BOS = *Lepidorombus boscii*; ILLE COI = *Illex coindetii*; MERL MERL = *Merluccius merluccius*; PHY BLE = *Phycis blennoides*; HYME ITA = *Hymenocephalus italicus*; LEPI CAU = *Lepidopus caudatus*; PAPE LON = *Parapenaeus longirostris*; GADI ARG = *Gadiculus argenteus*.

The first two axes of the principal component analysis (PCA) expressed 49% of the total variance. The presence of silver scabbardfish firstly and *P. longisostris* and *G. argenteus* secondarily, were associated with the catches carried out at west of the Lesvos islands at depths between 340 and 370 m. Comparing the geographical distribution of the scabbardfish and the sea surface temperature, it was found that the hotspots of scabbardfish biomass coincided with the longitudinal thermal front that is generated between the eastern (colder) and the western (warmer) surface water masses during the summer months (Figure 6). Considering the geographical distribution of *L. caudatus* (Figure 7), this area could be appropriately defined as silver scabbardfish fishing ground.

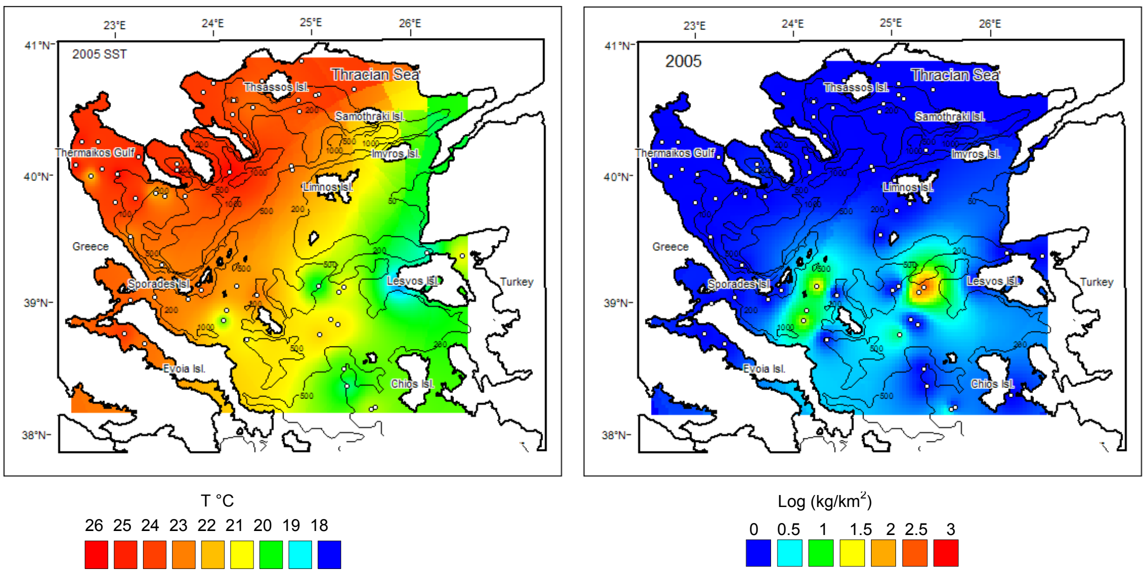

Fig. 6. Superficial water temperature (on the left) and fish biomass (on the right) spatial distribution, during MEDITS 2005

The results of the multiple regression analysis showed that the biomass was positively correlated only with coordinates in the west–east direction (Table 3) thus suggesting that scabbardfish biomass distribution followed a west-east gradient.

Table 3. Relation between *L. caudatus* biomass and fishing parameters

	R	SE	P
Intercept	-9.402	11.994	0.436
TD	-0.001	0.002	0.468
SST	0.043	0.037	0.242
BT	-0.673	0.366	0.071
E	0.660	0.137	<0.01
N	0.083	0.187	0.659

R = Regression coefficients; SE= Standard Error of R; P = probability level.
TD = hauls mean depth stratum; SST = superficial water temperature; BT = bottom water temperature; E = longitude; N = latitude.

Discussion

The results obtained by the bathymetric distribution analysis of the silver scabbardfish were in agreement with those of Demestre et al. (1993) in the Catalan sea (North western Mediterranean Sea) confirming that the continental upper slope is the ideal environment for the species (among 300 and 400 m depth in the North Aegean Sea). This research confirmed the presence of zones with high density of benthopelagic fauna in deep waters. The sustainability of the deep demersal resources exploitation depends on the structure of the food chain and its natural

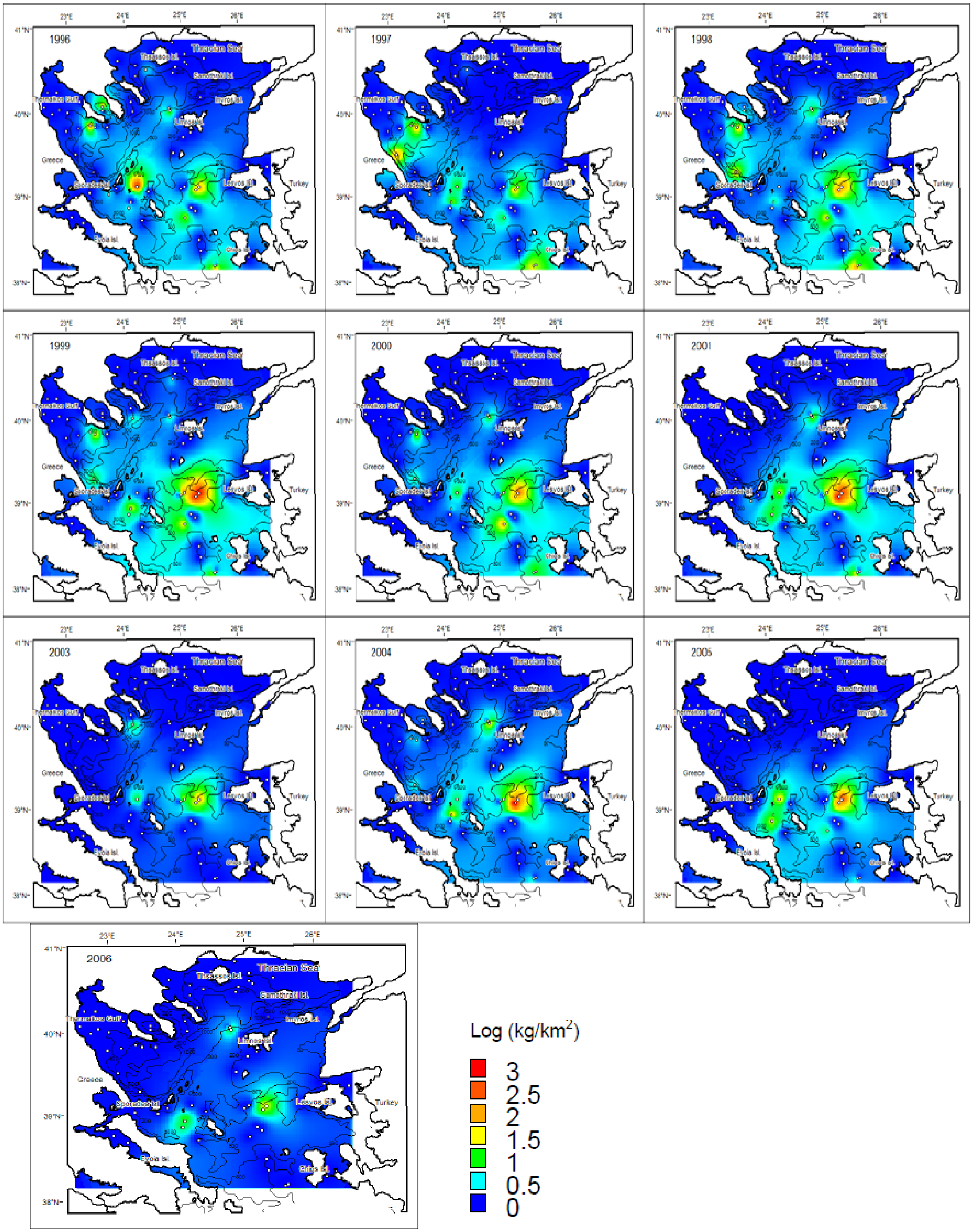

Fig. 7. Spatial distribution of *L.caudatus* biomass in the considered period from 1996 to 2006

productivity. In particular, the organic matter, that reaches the deep sea as passive transport, sustains the benthopelagic fauna of the upper slope (Mann and Lazier 1996). Studies conducted on feeding habits of fish and cephalopodos in the continental slope environment (Hulley 1984; Rasmussen and Giske 1994; Santos and Haimovici 1997; Stergiou and Karpouzi 2002; Bozzano et al. 2005) have shown that their principal food is constituted by fauna of mesopelagic environment (macrozooplankton and fishes). The mechanisms of energy transport from the surface layer of primary production to the deep demersal areas seems to be insured by the nycthemeral vertical prey migration (Mauchline and Gordon 1991; Rasmussen and Giske 1994; Rosland and Giske 1994; Linkowski 1996; Pinot and Jansà 2001; Hayashi et al. 2001; Hernánedez-Léon et al. 2002; Tarling et al. 2002; McClatchie and Dunford 2003). The dependence between benthopelagic fishes and mesopelagic prey availability is one of the principal factors that affects the productivity of the deep demersal areas (Green et al. 1988; McClatchie et al. 2005). In this area silver scabbardfish is an apex predator and it feeds on crustaceans (mainly euphasians and the decapods Pasiphaea), fishes (Mychtophidae and Gonostomatidae) or cephalopods (*Abralia* sp.) (Hayashi et al. 2001; Linkowski 1996; Tarling et al. 2002; Hernánedez-Léon 2002). Consequently, its presence directly depends on the availability of mesopelagic preys. From the geographical point of view, the distribution of the scabbardfish during summer months significantly increases along a west - east gradient and that the zones of higher abundance are related with the thermal front area that is generated between the eastern (colder) and the western (warmer) surface water masses. In the oriental sector of northern Aegean Sea there is an upwelling system strongly influenced by the action of the Etesian winds that mainly blow during the summer months (Stergiou and Lascaratos 1997; Bakun and Agostini 2001; Agostini and Bakun 2002; Hamad et al. 2006). This upwelling system produces a thermal front that is localized in the central area of the basin and it is clearly visible in the figure (Figure 6). Agostini and Bakun (2002) affirmed that the upwelled waters of the Aegean Sea are poorly productive. During the last MEDITS survey (2006) it was found that in correspondence of the thermal front there was a primary production transferred to deeper zones. On the light of these considerations, it is presumable that the high density of scabbardfish is primarily maintained by Euphausiids and other mesopelagic associated species such as *Gadiculus argenteus*, *Merluccius merluccius*, *Illex coindetii*, and *Parapenaeus longirostris*.

In conclusion, in this study the distribution of silver scabbardfish in the northern Aegean Sea is depicted and an hypothesis is suggested about the influence of the northern Aegean Sea upwelling system on the productivity and dynamic of scabbardfish.

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