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Trends in the abundance of demersal species in the southern Aegean Sea*

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SUMMARY: The present work identifies trends in the abundance of the main demersal species of the South Aegean Sea utilising catch and effort data derived from an international Mediterranean bottom trawl survey (MEDITS). The experimental surveys were accomplished annually from 1994 to 2000 on 61 pre-defined sampling stations. Selection of stations was based on a depth-stratified random sampling scheme that included five depth strata: 10-50, 50-100, 100-200, 200-500 and 500-800 m. The results suggest the existence of a general increasing trend in the biomass of the demersal species, particularly at the 10-50 m and 500-800 m depth strata. Findings are discussed in relation to the fisheries exploitation pattern and productivity of the area.

Key words: demersal, abundance, Aegean, Mediterranean.

INTRODUCTION

Due to the presence of numerous islands, the southern Aegean Sea has some unique topographical and bathymetrical features, which contribute to its zoogeographical distinction from the rest of the Aegean (Papaconstantinou, 1990). Fishing activities are widespread all over the area and groundfish trawling is very common, mainly at depths down to 300 m. As the continental shelf is very narrow, the existing measures that prohibit groundfish trawling within one mile from the coast make a large proportion of the area down to 100 m unavailable to the bottom trawl fishery. The latter is multi-specific, but similarly to other Mediterranean areas, a small group of species, such as red mullets, hake, shrimps,

etc., account for a large proportion of the total catch and its economic value (Caddy, 1993; Farrugio *et al*., 1993).

Past researchers have described the demersal fauna of the southern Aegean Sea and have related the species composition of the demersal communities with the depth and substrate characteristics of the area (Bellog, 1948; Ege, 1953; Papaconstantinou and Tsimenides, 1979; Tsimenides *et al*., 1991; Sinis and Koukouras, 1995; Tserpes *et al*., 1999). However, due to lack of standardised routine surveys, there is no information on the abundance fluctuation of the main demersal species inhabiting the area (Stergiou *et al.,* 1997a). During the last 15 years, commercial catches show an upward trend, similar to that of the whole Mediterranean (Papaconstantinou and Farrugio, 2000), but it is not known if such an increase reflects abundance

changes or is simply due to the intensification of fishing activities.

The present work attempts to investigate biomass abundance changes of the main demersal species of the southern Aegean Sea by using a time series of data collected within the framework of an international Mediterranean bottom trawl survey. Moreover, fluctuations in the overall abundance of the different depth zones by faunistic category are examined and the results are discussed in relation to the fishing activities carried out in the area.

MATERIALS AND METHODS

Within the framework of the "MEDITS" international trawl survey research program, seven annual bottom trawl surveys have been performed from 1994 to 2000 in the southern Aegean Sea (Bertrand *et al.*, 2000, 2002). The surveys, which were mainly aimed at obtaining estimates of abundance indices for a series of target species, were accomplished in summer (June-July), and each of them included sampling at 61 pre-defined stations distributed all over the sampled area (Fig. 1). Selection of stations was based on a depth-strati-

fied sampling scheme and the same sampling protocol was used in all cases (Bertrand *et al.*, 2000, 2002). The surveys covered the depth range from 10 m to 800 m and the total surface of the surveyed area was estimated to be up to 62,601 km^2. The surface of each depth zone was: 10-50 m: 4,918 km^2, 50-100 m: 4,090 km^2, 100-200 m: 13,269 km^2, 200-500 m: 18,100 km^2, 500-800 m: 22,224 km^2. The number of the annual hauls fluctuated between 40 and 60, being close to 60 since 1996. The fluctuation was due to: (a) the expansion of the sampling scheme introduced in 1996 and (b) the existence of adverse weather conditions that prevented sampling in certain cases.

From the collected data, abundance indices, expressed in terms of g/km^2 of swept area were computed separately for each station, for 14 out of 50 target species included in the MEDITS survey (Bertrand *et al.,* 2000, 2002). The selection of species was based on their: (a) accessibility to commercial bottom trawlers, (b) commercial interest and (c) importance in characterising the demersal fauna of the different depth strata of the southern Aegean Sea (see Tserpes *et al.* (1999) for details). Out of the 14 selected species, eight were fishes, four cephalopods and two crustaceans (Table 1). For each
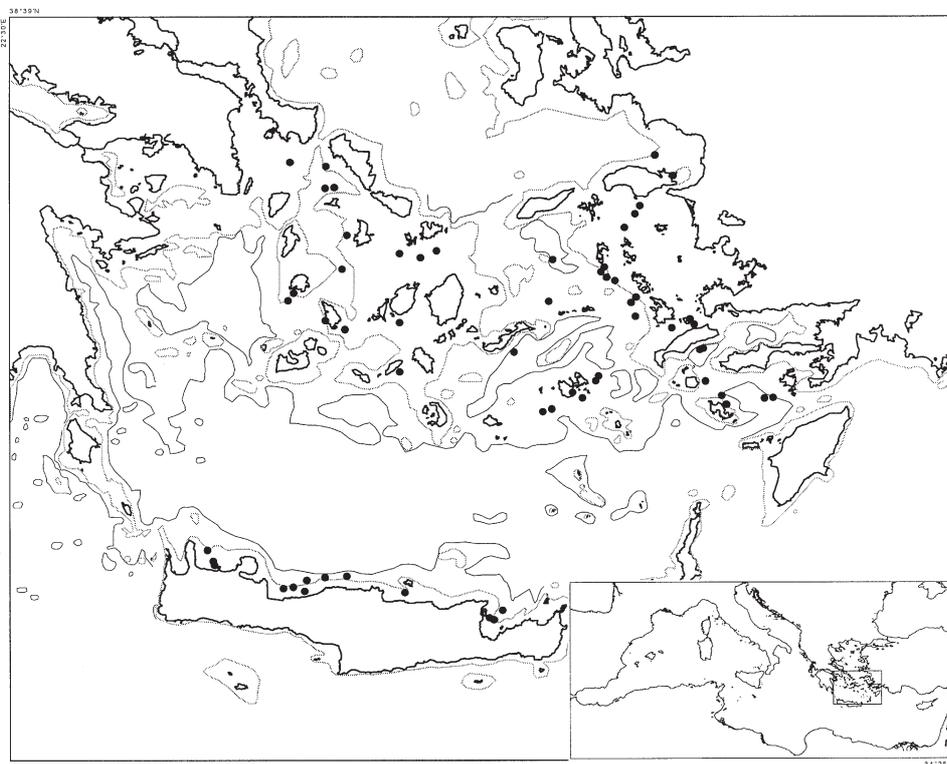

FIG. 1. – Map of the surveyed area indicating the position of the sampling stations (bullets) and the 200 and 500 m isobaths. The relative position of the surveyed area in the Mediterranean basin is shown on the right bottom sketch of the figure.

TABLE 1. – Depth zones examined for each species.

Species	10-50 m	50-100 m	100-200 m	200-500 m	500-800 m
Sepia officinalis	+	+	+		
Eledone moschata	+	+	+		
Octopus vulgaris	+	+	+		
Serranus cabrilla	+	+	+		
Pagellus erythrinus	+	+	+		
Mullus barbatus	+	+	+	+	
Mullus surmuletus	+	+	+	+	
Scyliorhinus canicula		+	+	+	
Eledone cirrhosa			+	+	
Squalus acanthias			+	+	+
Merluccius merluccius		+	+	+	+
Parapenaeus longirostris				+	+
Phycis blennoides				+	+
Aristeomorpha foliacea					+

station, the overall abundance index by faunistic category was also computed taking into account all target species of the survey (50 in total).

In order to examine the effects of year and depth in the abundance indices and identify time trends, in terms of both individual species and faunistic category, catch per unit effort (CPUE) indices were standardised using General Linear Model (GLM) techniques (Gulland 1956; Kimura, 1981). The general model used was of the form:

$$\ln(CPUE_{ij} + 1) = \mu + D_i + Y_j + interaction + \varepsilon_{ij},$$

where $CPUE_{ij}$: nominal CPUE at depth stratum i, in year j,

μ: overall mean,
D_i: effect of depth stratum i,
Y_j: effect of year j,
Interaction: two effect interaction, and
ε: error term assumed to be normally distributed.

The constant 1 was added to all CPUE rates to account for the zero observations. For each species, the analysis was confined to the depth zones where the species was mainly found (Table 1). The criterion used was its presence in at least 40% of the stations of the corresponding depth stratum. The analysis by faunistic category included all depth strata for fish (five in total: 10-50, 50-100, 100-200, 200-500, 500-800 m), four strata (all up to 500 m) for cephalopods and two for crustaceans (200-500, 500-800 m). To identify time trends, linear trend-lines were plotted on the standardised annual CPUE estimates.

The measure of goodness of fit of the models was the coefficient of determination (R^2). All statistical inferences were based on the 95% confidence level.

RESULTS

Analysis by species

Analysis of Variance (ANOVA) results for the GLMs fitted to the CPUE rates are presented separately for each species in Tables 2-4. Estimated R^2 values indicate that the models explained 12-28% of the total variation. The annual standardized CPUE indices and the fitted trend-lines are illustrated in Figs. 2-4. For five degrees of freedom (i.e. n = 7) significant trends at the 0.05 significance level were only those having a R^2 value higher than 0.57 (corresponding Pearson's correlation coefficient, r = 0.755). Significantly increasing abundance trends were found for six species: *Mullus barbatus, Mullus surmuletus, Phycis blennoides, Squalus acanthias, Parapenaeus longirostris* and *Aristeomorpha foliacea. Eledone cirrhosa* was the only species that showed a significantly decreasing trend, which however was marginal (R^2 = 0.571). The rest of the species did not show any significant trend. Standardized CPUE indices by species and depth stratum are presented in Fig. 5. The main findings are summarized in Table 5.

Analysis by faunistic category

The analysis included all target species of the "MEDITS" survey (Bertrand *et al*., 2000, 2002). ANOVA results are presented separately for each faunistic category in Table 6. In all cases the fitted GLMs explained about 20% of the total variation. The overall annual standardized CPUE indices and the fitted trend-lines are illustrated in Fig. 6. The corresponding indices and trend-lines by depth stratum are shown in Figs. 7-9. The main findings are summarized below.

TABLE 2. – ANOVA table for the GLMs fitted to each fish species.SS, Sum of Squares; MS, Mean Square.

Mullus barbatus (R² = 0.25)

Source	SS	df	MS	F	Sig.
Intercept	4349.6	1	4349.6	222.6	0
Year	88.9	6	14.8	0.7	0.603
Stratum	1584	3	528	27	0
Year * Stratum	156.2	18	8.6	0.4	0.977
Error	5685.5	291	19.5		
Corrected Total	7611.8	318			

Mullus surmuletus (R² = 0.16)

Source	SS	df	MS	F	Sig.
Intercept	5079.9	1	5079.9	254.5	0
Year	75.3	6	12.5	0.6	0.707
Stratum	758.8	3	252.9	12.6	0
Year * Stratum	202.9	18	11.2	0.5	0.923
Error	5806.5	291	19.9		
Corrected Total	6918.2	318			

Serranus cabrilla (R² = 0.15)

Source	SS	df	MS	F	Sig.
Intercept	6513.4	1	6513.4	410.9	0
Year	55	6	9.1	0.5	0.747
Stratum	198.1	2	99	6.2	0.002
Year * Stratum	114.3	12	9.5	0.6	0.839
Error	2346	148	15.8		
Corrected Total	2762.9	168			

Pagellus erythrinus (R² = 0.26)

Source	SS	df	MS	F	Sig.
Intercept	4033.9	1	4033.9	180.6	0
Year	101.7	6	16.9	0.7	0.603
Stratum	1006.5	2	503.2	22.5	0
Year * Stratum	72.9	12	6	0.2	0.993
Error	3304.5	148	22.3		
Corrected Total	4460.5	168			

Scyliorhinus canicula (R² = 0.25)

Source	SS	df	MS	F	Sig.
Intercept	8647.8	1	8647.8	426.6	0
Stratum	1566.1	3	522	25.7	0
Year	127.2	6	21.2	1	0.395
Stratum * Year	285.5	17	16.7	0.8	0.659
Error	6445.4	318	20.2		
Corrected Total	8550.3	344			

Squalus acanthias (R² = 0.27)

Source	SS	df	MS	F	Sig.
Intercept	4074.6	1	4074.6	164.8	0
Stratum	1417.3	2	708.6	28.6	0
Year	599.1	6	99.8	4	0.001
Stratum * Year	135.6	12	11.3	0.4	0.938
Error	6748.1	273	24.7		
Corrected Total	9218.7	293			

Merluccius merluccius (R² = 0.22)

Source	SS	df	MS	F	Sig.
Intercept	15998.8	1	15998.8	1133.6	0
Year	269.8	6	44.9	3.1	0.005
Stratum	379	3	126.3	8.9	0
Year * Stratum	731.8	18	40.6	2.8	0
Error	4600.6	326	14.1		
Corrected Total	5888.1	353			

Phycis blennoides (R² = 0.12)

Source	SS	df	MS	F	Sig.
Intercept	4340.5	1	4340.5	285.7	0
Stratum	11.2	1	11.2	0.7	0.391
Year	197.3	6	32.8	2.1	0.048
Stratum * Year	223.6	6	37.2	2.4	0.026
Error	2931.7	193	15.1		
Corrected Total	3331.3	206			

TABLE 3. – ANOVA table for the GLMs fitted to each cephalopod species. SS, Sum of Squares; MS, Mean Square.

Sepia officinalis (R² = 0.17)

Source	SS	df	MS	F	Sig.
Intercept	1739.8	1	1739.8	85.7	0
Stratum	329.8	2	164.9	8.1	0
Year	99.2	6	16.5	0.8	0.56
Stratum * Year	107.4	12	8.9	0.4	0.944
Error	3002.2	148	20.2		
Corrected Total	3633	168			

Octopus vulgaris (R² = 0.20)

Source	SS	df	MS	F	Sig.
Intercept	2981.2	1	2981.2	133	0
Stratum	410.8	2	205.4	9.1	0
Year	196.9	6	32.8	1.4	0.194
Stratum * Year	179.4	12	14.9	0.6	0.78
Error	3361.7	150	22.4		
Corrected Total	4186.2	170			

Eledone moschata (R² = 0.25)

Source	SS	df	MS	F	Sig.
Intercept	5060	1	5060	267.4	0
Year	193.6	6	32.2	1.7	0.123
Stratum	468.1	2	234	12.3	0
Year * Stratum	125.5	12	10.4	0.5	0.876
Error	2799.9	148	18.9		
Corrected Total	3727.1	168			

Eledone cirrhosa (R² = 0.28)

Source	SS	df	MS	F	Sig.
Intercept	1972.9	1	1972.9	140.1	0
Year	824.2	6	137.3	9.7	0
Stratum	118.3	1	118.3	8.4	0.004
Year * Stratum	314.1	6	52.3	3.7	0.002
Error	2842.6	202	14		
Corrected Total	3968.4	215			

TABLE 4. – ANOVA table for the GLMs fitted to each crustacean species. SS, Sum of Squares; MS, Mean Square.

Parapenaeus longirostris (R² = 0.17)

Source	SS	df	MS	F	Sig.
Intercept	4618.1	1	4618.1	262.6	0
Year	456.1	6	76	4.3	0
Stratum	108.5	1	108.5	6.1	0.014
Year * Stratum	182.2	6	30.3	1.7	0.116
Error	3340.5	190	17.5		
Corrected Total	4047.1	203			

Aristeomorpha foliacea (R² = 0.24)

Source	SS	df	MS	F	Sig.
Intercept	1456.8	1	1456.8	82.6	0
Year	239.2	5	47.8	2.7	0.032
Error	757.9	43	17.6		
Corrected Total	997.2	48			

Fish

ANOVA indicated that differences among years and depth strata were significant (Table 6). Annual standardized CPUE showed a significantly increasing trend with a R² value equal to 0.73 (Fig. 6).
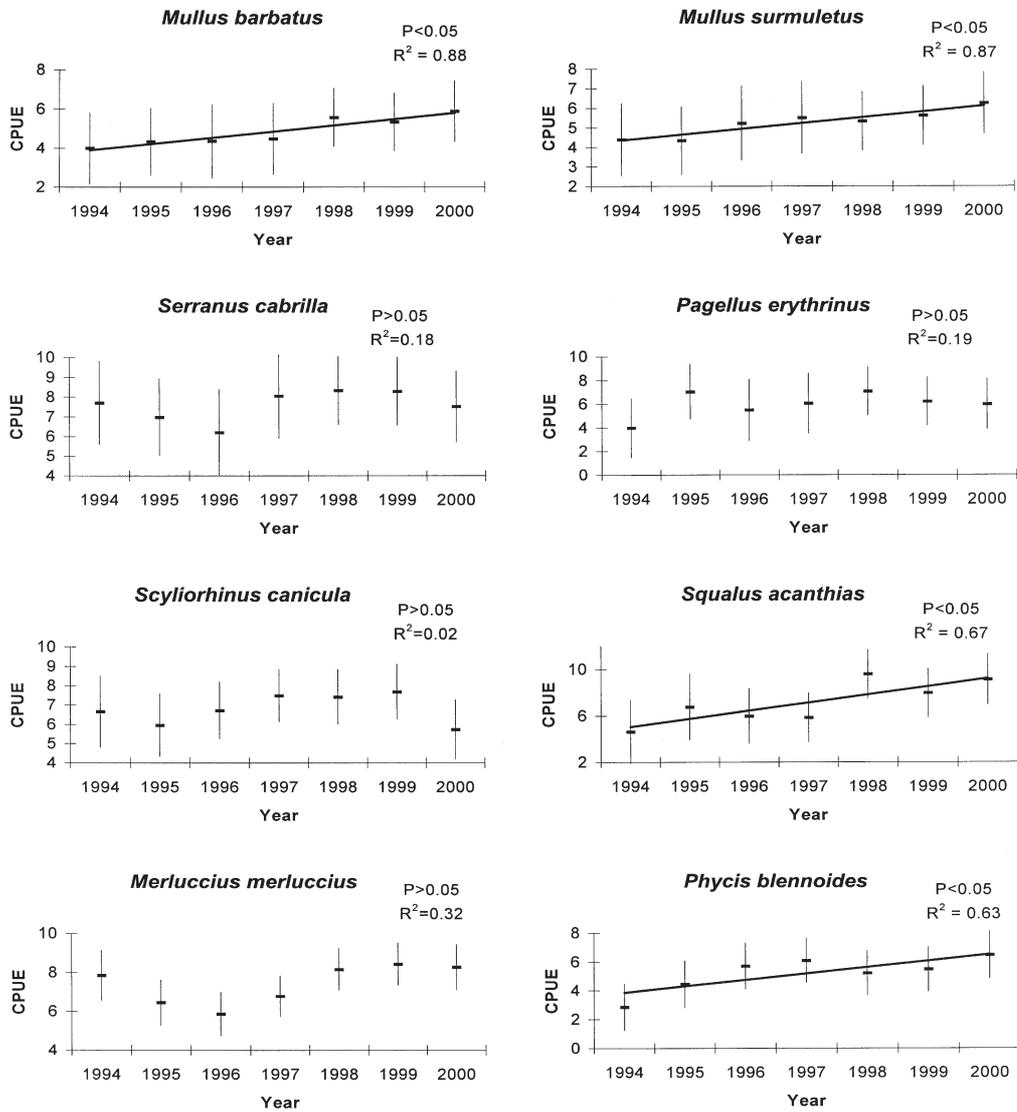
FIG. 2. – Standardised CPUE estimates expressed in ln (g/km²) by year and fish species. Vertical lines indicate the 95% confidence intervals of the corresponding estimates. Trend-lines indicate the presence of significant trends.
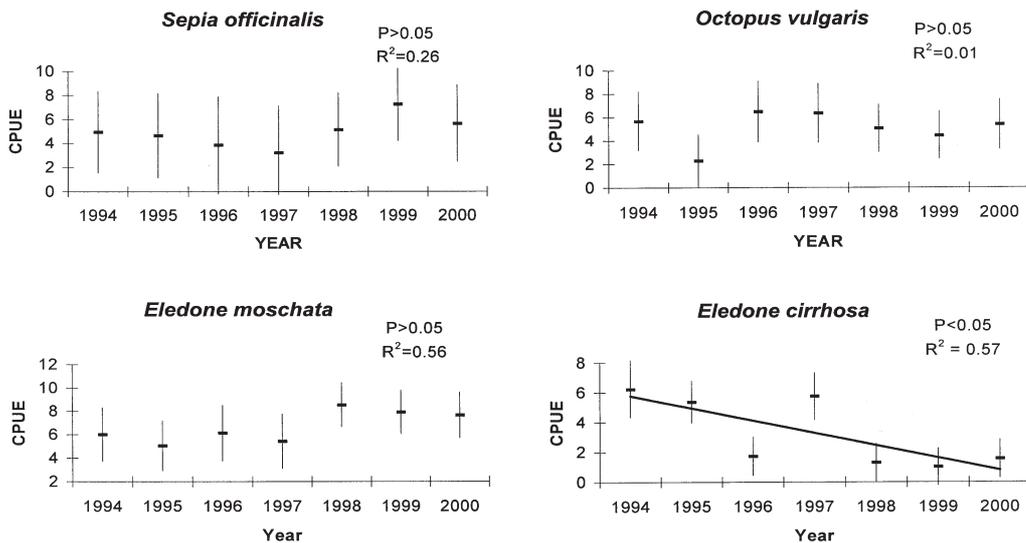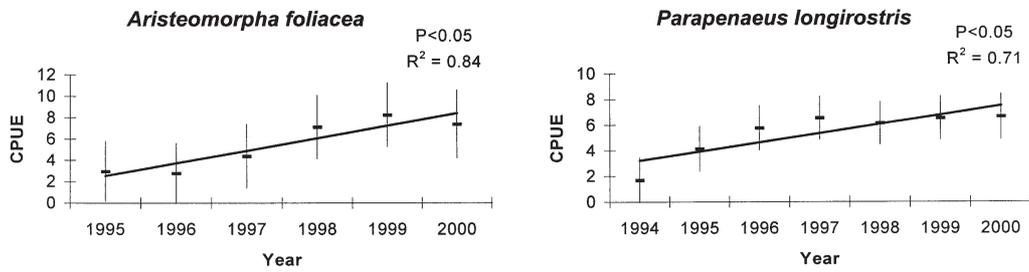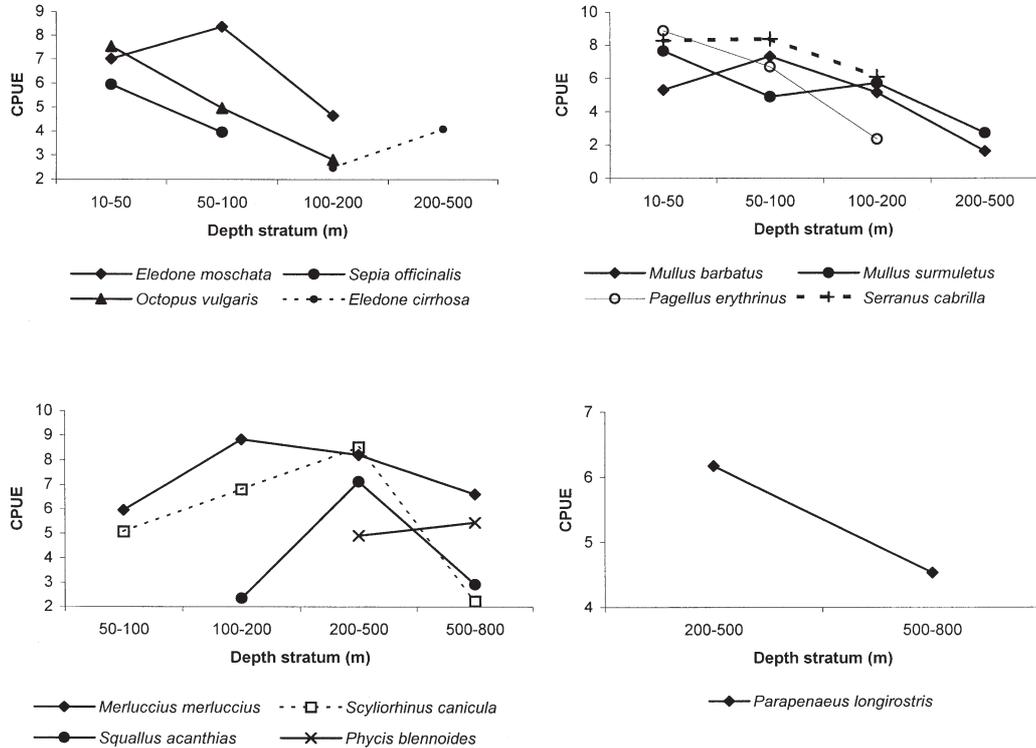

FIG. 3. – Standardised CPUE estimates expressed in ln (g/km²) by year and cephalopod species. Vertical lines indicate the 95% confidence intervals of the corresponding estimates. Trend-lines indicate the presence of significant trends.

FIG. 4. – Standardised CPUE estimates expressed in ln (g/km²) by year and crustacean species. Vertical lines indicate the 95% confidence intervals of the corresponding estimates. Trend-lines indicate the presence of significant trends.

FIG. 5. – Standardized overall CPUE estimates expressed in ln (g/km²) by species and depth stratum.

TABLE 5. – Summarised results by species of the fitted GLMs and linear trend-lines (see text for details). Tick-marks indicate the presence of significant differences.

| | ANOVA results | | | | |
	Stratum	Year	Stratum-year interaction	Depth strata of higher abundance	Significance of abundance trends
Merluccius merluccius	√	√	√	100-200, 200-500	No trend (R²=0.32, P>0.05)
Mullus barbatus	√			50-100	Increase (R²=0.88, P<0.05)
Mullus surmuletus	√			10-50	Increase (R²=0.87, P<0.05)
Pagellus erythrinus	√			10-50	No trend (R²=0.19, P>0.05)
Phycis blennoides		√	√	500-800	Increase (R²=0.63, P<0.05)
Scyliorhinus canicula	√			200-500	No trend (R²=0.02, P>0.05)
Serranus cabrilla	√			50-100	No trend (R²=0.18, P>0.05)
Squalus acanthias	√	√		200-500	Increase (R²=0.67, P<0.05)
Eledone cirrhosa	√	√	√	200-500	Decrease (R²=0.57, P<0.05)
Eledone moschata	√			10-50	No trend (R²=0.56, P>0.05)
Octopus vulgaris	√			10-50	No trend (R²=0.01, P>0.05)
Sepia officinalis	√			10-50	No trend (R²=0.26, P>0.05)
Parapenaeus longirostris	√			200-500	Increase (R²=0.71, P<0.05)
Aristeomorpha foliacea	√			500-800	Increase (R²=0.84, P<0.05)

TABLE 6. – ANOVA table for the GLMs fitted to each faunistic category. SS, Sum of Squares; MS, Mean Square.

Fish	(R² = 0.22)				
Source	SS	df	MS	F	Sig.
Intercept	34725.5	1	34725.5	6678	0
Stratum	144	4	36	6.9	0
Year	168.1	6	28	5.3	0
Stratum * Year	114.9	24	4.7	0.9	0.573
Error	1778.3	342	5.2		
Corrected Total	2279.7	376			

Cephalopods	(R² = 0.22)				
Source	SS	df	MS	F	Sig.
Intercept	18262.2	1	18262.2	2846	0
Stratum	118	3	39.3	6.1	0
Year	112.7	6	18.7	2.9	0.009
Stratum * Year	161.6	18	8.9	1.4	0.13
Error	1867	291	6.4		
Corrected Total	2399.1	318			

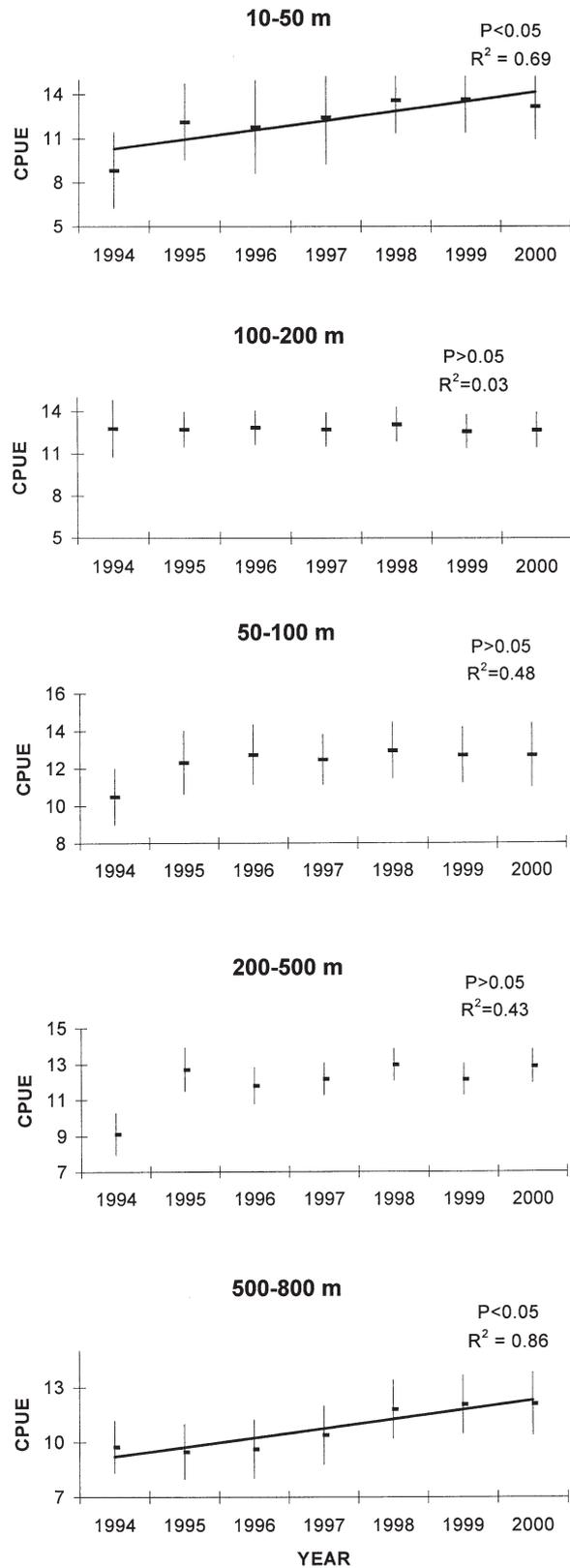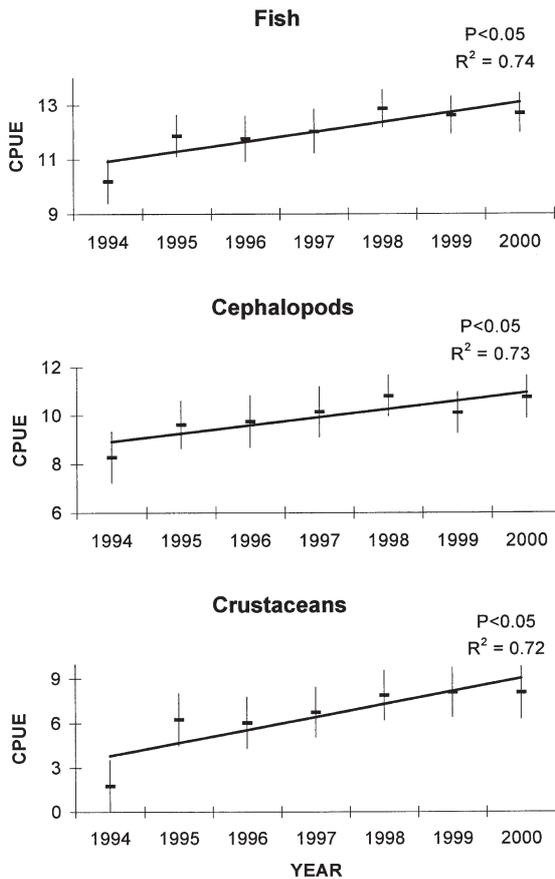| Crustaceans	(R² = 0.21)				
Source	SS	df	MS	F	Sig.
Intercept	6647.5	1	6647.5	376.4	0
Stratum	40.9	1	40.9	2.3	0.129
Year	671.6	6	111.9	6.3	0
Stratum * Year	409.6	6	68.2	3.8	0.001
Error	3408	193	17.6		
Corrected Total	4318.2	206			

FIG. 6. – Standardised CPUE estimates expressed in ln (g/km²) by year and faunistic category for all MEDITS species. Vertical lines indicate the 95% confidence intervals of the corresponding estimates. Trend-lines indicate the presence of significant trends.
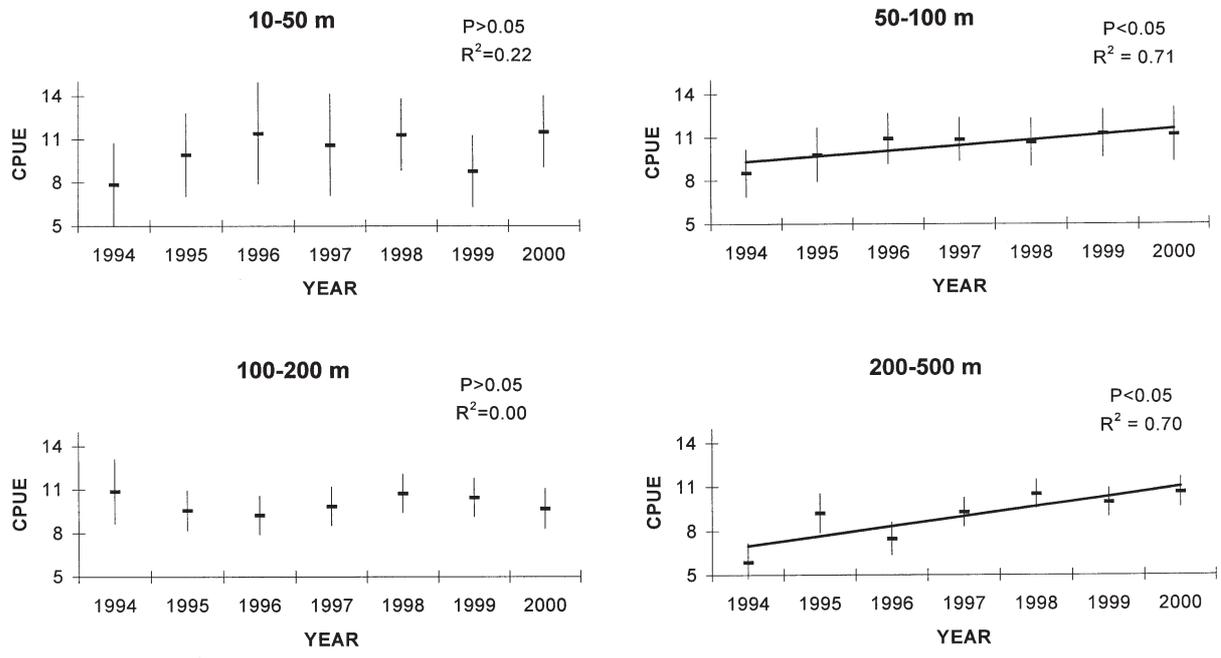
FIG. 7. – Standardised CPUE estimates expressed in ln (g/km²) by year and depth stratum for all MEDITS fish species. Vertical lines indicate the 95% confidence intervals of the corresponding estimates. Trend-lines indicate the presence of significant trends.

FIG. 8. – Standardised CPUE estimates expressed in ln (g/km²) by year and depth stratum for all MEDITS cephalopod species. Vertical lines indicate the 95% confidence intervals of the corresponding estimates. Trend-lines indicate the presence of significant trends.

Analysis by depth stratum demonstrated that the annual standardized CPUE increased significantly with time in the 10-50 and 500-800 m depth zones ($R^2 = 0.68$ and 0.85, respectively, $P<0.05$) while no significant trend was detected in the 100-200 and 200-500 m depth zones ($R^2 = 0.03$ and 0.43, respectively, $P>0.05$) (Fig. 7).

Cephalopods

ANOVA indicated that differences among years and depth strata were significant (Table 6). Annual standardised CPUE increased significantly with time ($R^2 = 0.72$, $P<0.05$) (Fig. 6). Analysis by depth stratum demonstrated that the annual standardised CPUE had a significantly increasing trend in the 50-100 and 200-500 m depth zones ($R^2 =$ 0.71 and 0.70, respectively, $P<0.05$) (Fig. 8). No significant trend was detected in the 10-500 and 100-200 m depth zones ($R^2 = 0.22$ and 0.00, respectively, $P>0.05$).

Crustaceans

ANOVA indicated that differences among years, as well as the year-depth stratum interaction were significant (Table 6). Annual standardised overall CPUE showed a significantly increasing trend ($R^2 = 0.71$, $P<0.05$) (Fig. 6). Analysis by depth stratum demonstrated that the annual standardised CPUE increased significantly with time for the 500-800 m depth zone ($R^2 = 0.84$, $P<0.05$). No significant trend was detected in the 200-500 m depth zone ($R^2 = 0.06$, $P>0.05$) (Fig. 9).

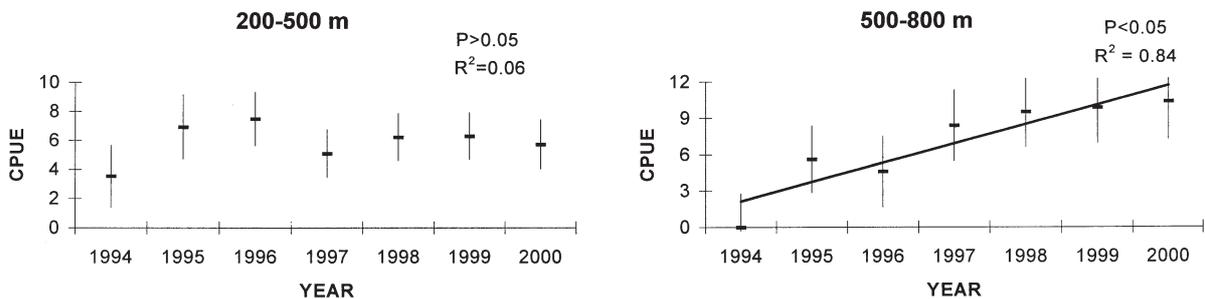FIG. 9. – Standardised CPUE estimates expressed in ln (g/km²) by year and depth stratum for all MEDITS crustacean species. Vertical lines indicate the 95% confidence intervals of the corresponding estimates. Trend-lines indicate the presence of significant trends.

DISCUSSION

The present study is the first attempt to examine biomass fluctuations of demersal species in the Aegean Sea. Other authors have analysed time series of catches of the Greek fishing fleets (Stergiou and Christou, 1996; Stergiou *et al.*, 1997b) but, due to lack of appropriate effort data, no comments could be made on aspects related to stock abundance. In the present case the use of generalised linear modelling permitted spatio-temporal comparisons and identification of time-trends. Although the available time-series of data was short for a full time series analysis, the results gave valuable information regarding the fluctuation of the demersal resources in the southern Aegean Sea. Similar techniques have been extensively used in the past for analysing catch-effort data, mainly in the Atlantic and Pacific areas (Gulland, 1956; Gavaris, 1980; Kimura, 1981; Punt *et al.*, 2000). In the case of the Mediterranean Sea, application of general linear modelling in catch-effort data from commercial bottom trawlers provided useful information on the fluctuation of hake stocks in the western Mediterranean (Goñi *et al.*, 1999). Estimates of experimental surveys like "MEDITS" may be affected by the limited duration of the surveys but they are independent of factors such as fisheries behaviour that could bias those estimates based on commercial data.

Our results suggest the existence of a general increasing trend in the biomass of the demersal fauna of the southern Aegean Sea. The eastern Mediterranean was formerly considered as an area of low productivity but it seems that the situation has changed in recent years and there are indications of increased eutrophication in several areas including the Aegean Sea (Bethoux *et al.* 1998; Caddy *et al.,* 1995; Papaconstantinou and Farrugio, 2000; Theocharis and Lascaratos, 2000). It is possible that the increased productivity has favoured recruitment of several species resulting in a total biomass increase.

An increasing trend in the commercial landings over the last 15 years can also be observed from the records of the National Statistical Service of Greece (Stergiou *et al.,* 1997b). Pauly *et al.* (1998), who analysed historical FAO fish landings statistics, pointed out that the increasing trend of the world landings during the last 45 years is accompanied by a general decrease of their mean trophic level due to a gradual transition from long-lived, high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous fish. Stergiou and Koulouris (2000) based on the catch data of the National Statistical Service of Greece concluded that this argument is generally justified in the Aegean Sea. The above approach, known as the "fishing down the food web" theory, hints that the abundance of species belonging to high trophic levels (e.g. demersals) should decline with time. The present findings do not support this theory that, however, has been criticised by Caddy *et al.* (1998) as oversimplifying a complicate situation.

It is noticeable that the stronger increasing trends have been observed in the 10-50 and the 500-800 m depth strata. Both strata undergo less fishing pressure than the remaining depth ranges due to the established fishing limitations and the behaviour of the fishermen. Thus, both strata are very little or not at all exploited by trawlers.

The existing measures that do not allow groundfish trawling within one mile from the coast make the 10-50 m depth stratum in an area with a narrow continental shelf, such as the southern Aegean, practically unavailable to the trawlers. In addition, as traditionally happens in most Mediterranean areas, fishing activities are focused on the continental shelf, leaving the slope, and particularly areas deeper than 500 m, less disturbed (Caddy, 1993). The above fishing pattern may, at least partially, explain the fact that the highly exploited 100-200 m depth stratum did not show any increasing trend as did the other strata.

Regarding trends at the species level, species that mainly inhabit the slope showed significantly increasing trends. This was particularly true in the case of the red shrimp *A. foliacea*, which inhabits the deeper part of the slope (>500 m). Moreover, two coastal species, such as the red and striped mullets *(Mullus barbatus* and *M. surmuletus)*, which are among the main target species of several fisheries, showed significantly increasing trends. Based on the aforementioned indications on increased productivity, it can be speculated that such a situation has supported recruitment and growth rates that compensate for the high fishing pressure imposed on these species in coastal areas. It is also expected that the closed season for bottom trawlers operating in the Greek seas from June to the end of September, favours the survival of recruits. Finally, the ability of some *Mullus* species, such as *M. barbatus,* to delay their settlement until they reach suitable substrates (Kendall *et al.*, 1984), may also further contribute to a successful recruitment.

Eledone cirrhosa was the only species that showed decreasing trends while *E. moschata*, which is a more coastal species than its congeneric, showed an increasing, however not significant, trend. This finding cannot be easily explained, but since both are short-lived species (Boyle, 1983; Mangold, 1983) it is very likely that their biomass fluctuations follow their recruitment pattern. Consequently, it seems that in the area there were conditions that favoured recruitment of *E. moschata* and undermined that of *E. cirrhosa*. This is not unlikely as the species differ in their reproduction period (Mangold *et al*., 1971; Mangold, 1983).

As the surveys have been carried out at the end, or just after the reproduction period of several species, it was thought that findings could be biased in some cases due to the irregular presence of recruits in the samples. For this reason, the use of biomass indices was preferred over the numeric ones, since they are expected to be less sensitive to spatio-temporal fluctuations due to the presence of recruits.

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