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A spatial analysis of the commercial fisheries catches from the Greek Aegean Sea☆

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Abstract

In the present study, univariate (number of species, species diversity, eveness, richness) and multivariate analysis techniques (cluster analysis and multidimensional scaling) are used, together with dominance curves, to describe the major biogeographical features of the demersal and pelagic fisheries in ten Greek statistical fishing subareas of the Aegean Sea for the years 1982–1987, inclusive. The results from the various statistical techniques applied were in close agreement and all suggested that the ten statistical fishing subareas could be generally grouped into three main areas (northern, central and southern Aegean Sea) for the pelagic fishery and into two main areas (northern and southern Aegean Sea) for the demersal fishery, which differed considerably from each other in terms of species composition, species diversity and catch density (catch weight per unit area). In general, with respect to the pelagic fisheries, the catches from the northern, central and southern Aegean area groupings are dominated, respectively, by anchovy (*Engraulis encrasicolus* (L.), 48.2%), horse mackerels (*Trachurus* spp., 23.2%) and bogue (*Boops boops* (L.), 40.6%). For the demersal fisheries, the catches from the northern and southern Aegean area groupings are dominated by grey mullets (Mugilidae, 10.3%) and pickerel (*Spicara smaris* (L.), 28.6%), respectively. The main factors which appear to be contributing to this geographical group differentiation are: (a) the gradient in the relative eutrophy, river runoff, temperature and salinity of the Aegean Sea waters along a NNW to SSE axis; and (b) the differences in extent of the continental shelf within these areas of the Aegean Sea. The managerial implications of the results of these spatial analyses are discussed and emphasis is given to the experimental establishment of marine harvest refugia which provide a refuge for fish populations in space, rather than the 'refuge in numbers' which has been the basis of most traditional fisheries management measures so far applied in this area.

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1. Introduction

In Greece, where the total length of the coastline is over 15 000 km, fisheries production should play a very important role in the national economy. In recent years, however, total Greek fisheries production has levelled off at about 150 000 t, in contrast to a gradual rise in fishing effort (Stergiou and Petrakis, 1993). This suggests that many of the fisheries resources upon which the Greek fishing industries are based may be either fully exploited or overfished. This is especially true of the demersal resources (Stergiou and Petrakis, 1993) as opposed to their pelagic counterparts (Stergiou et al., 1993). Overall, fisheries production is inadequate to meet local needs and net imports of fishery products are currently well over 40 000 t per year (Stergiou and Petrakis, 1993). The need for rational fisheries management is therefore urgent. Attempts have therefore been made to describe and assess the state of, and to model and predict, fisheries production in Greek waters from commercial fisheries catch statistics (e.g. Stergiou and Petrakis, 1993 and references therein), and also from analysis of data obtained from experimental trawl (e.g. Papaconstantinou et al., 1989) and acoustic surveys (e.g. Stergiou et al., 1993).

As there has not previously been a comprehensive analysis of the major features of the Greek Aegean Sea fisheries, in the present study univariate and multivariate analysis techniques are used together with dominance curves to characterize the major spatial features of the demersal and pelagic fisheries of this area for the years 1982–1987, inclusive. The Greek Ionian Sea fishing areas were not included in the present analysis because they comprise part of a larger area in which the existing stocks are also fished by a number of other major fishing nations (especially Albania, Italy, Libya, Malta and Tunisia); the mean Greek catch from the Ionian Sea over the period 1982–1987 represented only 7% of the total Ionian Sea catch (FAO, 1989). In contrast, the Aegean Sea is fished mainly by the Greek fleet. Although the Turkish fleet fishes along the eastern Aegean coast, the Turkish catch from this area is relatively small when compared with that of the Greek Aegean Sea fisheries; it comprised about 20% of the mean total Aegean catch over the period from 1982 to 1987 (FAO, 1989).

The overall aim of the present study, therefore, was to characterize the major spatial features of the Greek fisheries of the Aegean Sea by univariate and multivariate analyses of catch landing figures. This will be beneficial for the reorientation of the management of the Greek fisheries resources, especially if a common fishery policy is to be enforced throughout the Mediterranean Sea.

2. Materials and methods

Fisheries statistics for Greek waters have been recorded on a monthly basis since January 1964 by the National Statistical Service of Greece (NSSH). For a better evaluation of the available data, the waters fished by Greek vessels have been divided into 18 statistical fishing subareas (Fig. 1). Fishing subareas 1 and 2 (not shown in Fig. 1) refer to the Atlantic Ocean and the northern coast of Africa, respectively.

Catch data from Greek fisheries are collected directly from a sample of fishing vessels which are surveyed by local customs authorities. For each vessel surveyed, a statistical questionnaire is completed showing the quantities of each major fish species (or group of species) caught during the previous month (or that the vessel did not work during that period).

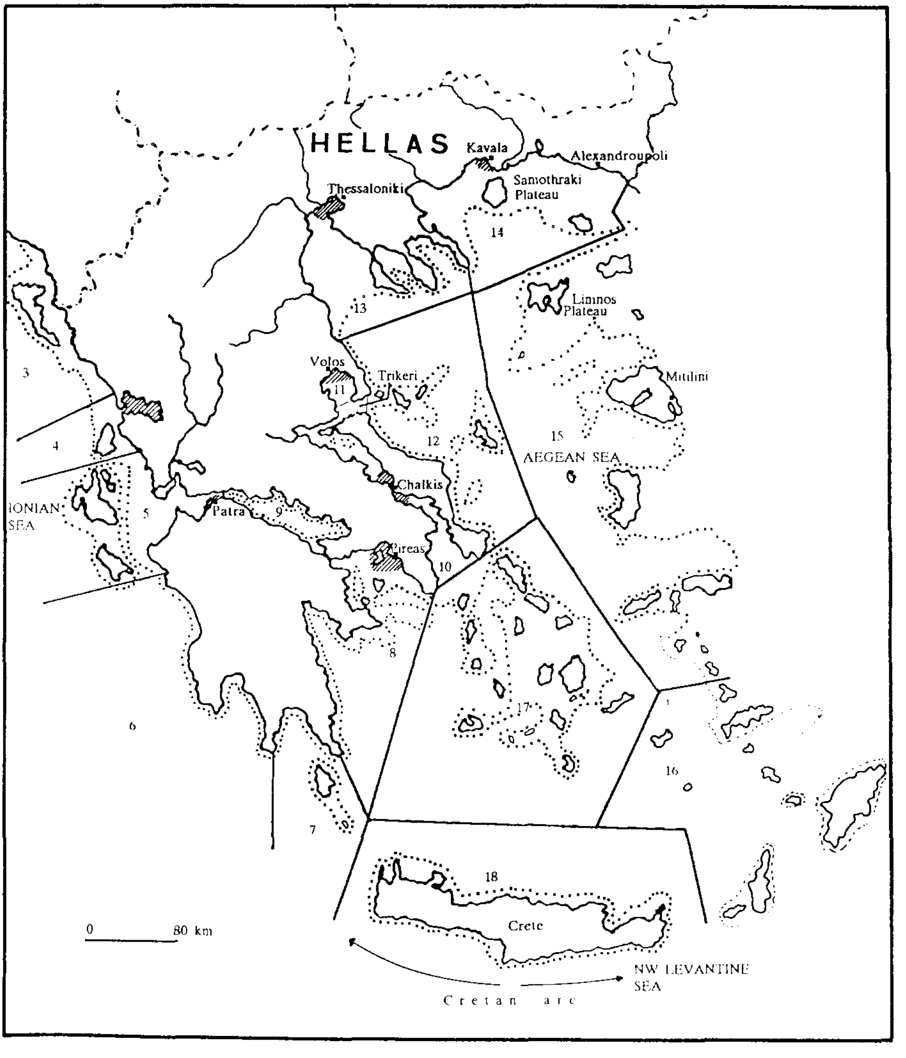


Fig. 1. Map showing fishing subareas in Greek waters. The dotted line represents the 200 m isobath. Hatched areas show areas in which man-made eutrophication may be locally important.

Table 1
Common names, scientific names and percentages of mean annual total catches (Aegean and Ionian Seas combined) of the 66 species (or groups of species) recorded by the National Statistical Service of Greece (NSSH, 1985–1989) fished by trawlers (T), purse seiners (P), beach seiners (S) and 'other coastal boats' (O, small ring netters, liners, drifters, etc.) over the period 1982–1987. Species are listed in alphabetical order with respect to common name

Common name	Scientific name	T	P	S	O
Fishes					
Anchovy	*Engraulis encrasicolus* (L.)	1.9	95.4	0.9	1.8
Anglerfishes	*Lophius* spp.	94.9	0.4	0.6	4.0
Annular sea bream	*Diplodus annularis* (L.)	8.8	13.3	0.8	77.1
Black sea bream	*Spondyliosoma cantharus* (L.)	13.7	6.8	6.0	73.6
Blotched pickerel	*Spicara flexuosa* Rafinesque, 1810	49.5	7.6	11.6	31.2
Blue whiting	*Micromesistius poutassou* (Risso, 1826)	93.8	0.5	3.3	2.4
Bluefin tuna	*Thunnus thynnus* (L.)	0.3	39.7	0.6	59.4
Bluefish	*Pomatomus saltator* (L.)	6.0	36.5	2.0	55.5
Bogue	*Boops boops* (L.)	11.0	51.8	11.8	25.4
Bonito	*Sarda sarda* (Bloch, 1793)	1.4	64.5	2.1	32.0
Brill	*Scophthalmus rhombus* (L.)	83.4	2.8	0.2	13.6
Chub mackerel	*Scomber japonicus* Houttuyn, 1782	3.3	82.7	3.8	10.3
Comber	*Serranus cabrilla* (L.)	32.6	5.8	2.1	59.6
Common dentex	*Dentex dentex* (L.)	9.3	2.6	5.3	82.8
Common sea bream	*Pagrus pagrus* (L.)	6.9	1.7	2.1	89.2
Dogfishes	Squalidae	37.0	4.3	0.6	58.1
Dusky grouper	*Epinephelus guaza* (L.)	3.5	5.2	1.5	89.8
European eel	*Anguilla anguilla* (L.)	2.2	5.1	0.7	92.0
European sardine	*Sardina pilchardus* (Walbaum, 1792)	1.7	77.9	9.0	11.4
European sea bass	*Dicentrarchus labrax* (L.)	24.6	14.4	3.0	58.0
Garfish	*Belone belone gracilis* Lowe, 1839	0.9	11.3	10.3	77.5
Gilt sardines	*Alosa falax nilotica* (Geoffrey Saint-Hilaire, 1808) and *Sardinella aurita* Valenciennes, 1847	5.4	70.2	2.1	22.2
Gilthead sea bream	*Sparus aurata* L.	71.6	7.8	2.8	17.8
Greater amberjack	*Seriola dumerili* (Risso, 1810)	21.5	24.0	4.0	50.5
Grey mullets	Mugilidae	9.5	17.3	0.7	72.5
Guitarfishes	*Rhinobatos* spp.	65.5	1.1	4.7	28.7
Gurnards	Triglidae	35.4	0.8	8.6	55.2
Hake	*Merluccius merluccius* (L.)	69.4	3.9	2.0	24.7
Horse mackerels	*Trachurus* spp.	17.3	67.7	4.0	11.0
Jack mackerel	*Trachurus picturatus* (T.E. Bowdich, 1825)	23.4	67.7	4.4	4.5
John dory	*Zeus faber* L.	79.6	0.8	3.8	15.8
Large-eye dentex	*Dentex macrophthalmus* (Bloch, 1791)	51.4	2.3	4.9	41.4
Mackerel	*Scomber scombrus* L.	7.9	60.3	2.9	28.8
Pickerel	*Spicara smaris* (L.)	22.2	9.0	45.5	23.3
Rays	*Raja* spp.	88.0	0.2	0.4	11.3
Red mullet	*Mullus barbatus* L.	72.6	3.1	5.2	19.1
Red pandora	*Pagellus erythrinus* (L.)	53.0	1.9	5.3	39.8
Rockfish	*Helicolenus dactylopterus* (Delaroche, 1809)	66.6	3.1	4.7	25.7
Saddled bream	*Oblada melanura* (L.)	12.4	17.3	4.0	66.4
Salema	*Sarpa salpa* (L.)	4.9	24.5	3.1	67.5
Scorpionfishes	*Scorpaena* spp.	24.7	4.4	2.7	68.3
Shi drum	*Umbrina cirrosa* (L.)	33.5	4.7	1.5	60.3

Common name	Scientific name	T	P	S	O
Skipjack	*Katsuwonus pelamis* (L.)	2.4	76.4	1.9	19.4
Smoothhounds	*Mustellus* spp.	38.1	36.5	0.5	24.9
Soles	Soleidae (mainly *Solea vulgaris* Quensel, 1806)	13.5	3.4	0.5	82.7
Sprat	*Sprattus sprattus* (L.)	9.5	68.8	4.4	17.3
Stone bass	*Polyprion americanus* (Schneider, 1801)	4.5	13.7	2.9	78.9
Striped red mullet	*Mullus surmuletus* L.	37.4	2.4	7.3	52.9
Swordfish	*Xiphias gladius* L.	4.1	5.0	1.0	89.9
Thick blotched pickerel	*Spicara maena* (L.)	9.3	22.5	10.7	57.6
Thornback ray	*Raja clavata* L.	89.0	1.0	0.2	9.8
Tub fish	*Trigla lucerna* L.	75.1	4.1	2.1	18.6
White grouper	*Epinephelus aeneus* (Geoffrey Saint-Hilaire, 1817)	27.7	2.3	2.6	67.3
White sea bream	*Diplodus sargus* (L.)	9.6	6.9	5.5	78.0
Whiting	*Merlangius merlangus euxinus* (Nordmann)	66.5	6.2	0.6	26.8
Other fish[a]		28.2	10.7	4.3	56.8
Cephalopoda					
Common squid	*Loligo vulgaris* Lamarck, 1798	45.0	3.9	30.5	20.7
Cuttlefish	*Sepia officinalis* L.	30.4	1.0	3.1	65.5
Flying squid	*Illex coindetii* (Verany, 1839)	94.1	0.7	1.9	3.3
Octopus	*Octopus vulgaris* Cuvier, 1797	48.6	1.6	6.8	43.0
Poulpes	*Eledone* spp.	97.9	0.3	0.8	1.1
Crustaceans					
Crabs[b]	Brachyura	30.5	0.0	0.8	68.7
Crayfish	*Nephrops norvegicus*	92.9	0.6	1.5	4.9
Lobsters	*Homarus gammarus* (L.) and *Palinurus elephas* (Fabricius, 1787)	5.1	0.6	0.9	93.4
Common prawn	*Penaeus kerathurus* (Forsskal, 1775)	65.8	1.0	3.1	30.1
Shrimps[b]	Natantia	69.8	0.4	0.5	29.3

[a]No data concerning species composition.
[b]Variety of species.
Sum across lines is 100%.

In general, the Greek fishing fleet includes: (a) fishing vessels operating in distant waters (Atlantic Ocean and northern African coast, and thus of no concern to the present study); (b) trawlers operating in Greek open-sea waters; (c) purse-seiners operating in Greek open-sea and coastal waters; (d) inshore seiners operating along the Greek coastline; and (e) 'other coastal boats' (including small ring netters, drifters, liners, etc.) operating along the coasts of Greece.

Since 1969 the catches of the smaller inshore ring netters, drifters and liners (i.e. boats with engine horsepowers of less than 20HP) have not been recorded by the local customs authorities. In addition, the catches from the marine sport fisheries, which locally may be relatively important (e.g. 11.8% and 4.5% of the total catches from subareas 9 and 5, respectively; Stergiou et al., 1989), are not included in the totals.

Since 1982 separate catch statistics have been available for 66 species (or groups of species) of commercially important fishes, cephalopods and crustaceans (Table 1). In order to allocate the 66 species (or groups of species) listed in the official catch statistics to either of the two primarily demersal or primarily pelagic catch categories, the catches of each species (or group of species) were first examined in relation to their primary method of capture (Table 1). Those fish species classified as being caught mainly by the trawl and inshore seine netting methods and by 'other coastal boats' were categorized as primarily demersal species, and those caught mainly by the purse-seining method as primarily pelagic species.

A number of species caught by both of these two broad groups of methods, however, presented some problems in their classification into either the primarily demersal or primarily pelagic categories. These included several semi-pelagic offshore species and several shallow water inshore surface-dwelling species. The bogue, for instance, is found throughout the water column, but because it is mainly caught by the purse seining method (Table 1), it was classified in the primarily pelagic category for the purposes of this study. The surface-dwelling garfish, though an inshore species, was also classified as primarily pelagic for the purposes of this analysis (caught by 'other coastal boats', purse-seine and seine netting methods, in that order, Table 1), as were the gilt sardines (caught primarily by the seine netting method and 'other coastal boats', Table 1).

A number of other inshore semi-pelagic species, including the pickerel, blotched pickerel, thick blotched pickerel, grey mullets, bluefish and greater amberjack, were classified here as primarily demersal because all are mainly caught by the seine and trawl netting methods and by 'other coastal boats' (Table 1). The only two other primarily pelagic species which are not caught by purse-seining were the swordfish and bluefin tuna, both of which are large pelagic forms.

In the present study, the annual landed catches of these 66 species (or groups of species) in the ten Aegean Sea statistical fishing subareas (8 and 10 to 18; Fig. 1) for the years 1982–1987, inclusive, were obtained from the annual bulletins of the NSSH (1985–1989). The annual landed catches per statistical fishing subarea, which are the best statistical figures available, were analyzed using three main categories of statistical techniques, as follows.

2.1. Descriptive univariate analysis

The following univariate measures were computed: (a) number of species, species diversity, richness and evenness for each subarea/year catch combination over the 1982–1987 period; (b) mean catch weight for each subarea over the 1982–1987 period; and (c) mean catch density for each subarea over the 1982–1987 period. Catch density is here defined as catch weight per unit of water area for the primarily pelagic and total fisheries, and as catch weight per unit of continental shelf area for the primarily demersal fisheries. The water and continental shelf areas of the 10 subareas are shown in Table 2.

Diversity was calculated using the Shannon-Wiener diversity index H′, species richness using Margalef's D, and evenness using Pielou's J (Maguran, 1988). All computations were carried out using the PRIMER algorithms of Plymouth Marine Laboratory (Clarke and Warwick, 1989).

Table 2
Water area and continental shelf area, in km^2, of the 10 fishing subareas (see Fig. 1) in the Greek Aegean Sea waters (modified from Kotsolios, 1992)

Subarea	Water area	Continental shelf area
S8	15360	5120
S10	3960	3800
S11	673	673
S12	18688	8993
S13	12800	5090
S14	11520	7927
S15	46080	8869
S16	39680	5570
S17	43520	13328
S18	40960	3392

2.2. Multivariate analyses

Matrices comprising the landed commercial catch weight of each species (or group of species) from each subarea for each year over the 1982–1987 period were compiled. From these catch matrices, triangular matrices of similarities between all pairs of subareas for each year were computed using the Bray-Curtis coefficient (Bray and Curtis, 1957). Prior to this computation, the data were standardized by the total landed catch/subarea in order to compensate for between-subarea differences in fishing effort, for which data per subarea are not given in the bulletins of the NSSH. Subsequently, the similarity matrices were subjected to both clustering (employing group-average linking) and ordination (employing non-metric multidimensional scaling, or MDS) analysis techniques. The results of the cluster analyses are displayed in the form of dendrograms, and those of MDS as two-dimensional 'maps' of the subarea/year combinations. In the latter, the more similar two subarea/year combinations are, in terms of their species (or groups of species) compositions, the closer they are to each other on the map; hence, the configurations have arbitrary orientation and scale. The adequacy of the ordination in two, rather than more than two, dimensions is expressed by a 'stress coefficient' (Field et al., 1982). In general, stress values <0.1 imply good representation (Clarke and Warwick, 1989). Discontinuities within and between subareas may be accepted as real when the results of the two methods agree (Field et al., 1982; Clarke and Green, 1988; Gray et al., 1988). In addition, since group-average numerical classification forces observations into existing clusters somewhat artificially, the complementary use of ordination is also useful for checking for misclassifications by cluster analysis (Vecchione and Grant, 1983). All multivariate analyses were carried out using the PRIMER algorithms (Clarke and Warwick, 1989).

The mean total catch weight and mean total catch density for each subarea over the period 1982–1987, and for each group of subareas indicated by the multivariate analyses, were tested for statistical differences between subareas and groups of subareas, respectively, using one-way analysis of variance (ANOVA) applied to log-tranformed data. The subareas, or groups of subareas, responsible for the statistical differences in the mean total catch weights and densities were identified using Fisher's least siginificant difference (LSD) test (Zar, 1984).

2.3. K-dominance curves

K-dominance curves represent a graphical method in which percentage cumulative abundance is plotted against log species rank. When two different *K*-dominance curves do not overlap, the upper curve will represent the assemblage most dominated by a few species and thus that which is less diverse (Lambshead et al., 1983; Platt et al., 1984). In the present study, *K*-dominance curves, based on the standardized mean catch weight over the 1982–1987 period, were plotted for each of the groups of subareas indicated by the multivariate analyses.

3. Results

The mean annual Greek (Aegean and Ionian Seas) fisheries catch during 1982–1987 amounted to 99, 905 t, of which 83, 343 t was caught in the Aegean Sea. Fish made up 94.7% of the mean total Aegean Sea catch, cephalopods 3.0% and crustaceans 2.3%.

The mean Aegean Sea catch of the primarily demersal species during 1982–1987 amounted to 33, 644 t and comprised 40.4% of the mean total Aegean catch over this period (Table 3). Overall, the pickerel dominated the catch, representing 16.0% of the mean demersal landed catch, followed by hake (7.6%), grey mullets (6.1%), striped red mullet (4.7%) and red mullet (4.4%) (Table 3). In addition, another 18 species (or groups of species) each contributed between 1 and 3% (Table 3).

The mean Aegean Sea catch of primarily pelagic species during 1982–1987 amounted to 49, 699 t and comprised 59.6% of the mean total Aegean catch over this period (Table 4). Overall, the anchovy, sardine, horse mackerels and bogue dominated the catch, representing 33.2%, 20.3%, 15.1% and 13.5% of the mean pelagic catch, respectively (Table 4). In addition, the chub mackerel, bluefin tuna, bonito and jack mackerel comprised 5.6%, 3.6%, 2.6% and 2.5% of the mean pelagic catch, respectively (Table 4). The remaining seven species each contributed less than 2% (Table 4).

With respect to both fisheries combined (analytic data not shown), the two pelagic species anchovy and sardine were dominant, comprising 19.8% and 12.1% of the mean total Aegean Sea catch, respectively, over this period. In addition, the horse mackerels, bogue, pickerel, chub mackerel, hake, grey mullets and blufin tuna comprised 9.0%, 8.0%, 6.5%, 3.3%, 3.1%, 2.4% and 2.1% of the mean catch, respectively. All of the remaining species each contributed less than 2%.

The mean annual catch weight, mean number of species comprising the catch, and the mean diversity indices (diversity, eveness, richness) over the ten subareas for the primarily pelagic, primarily demersal and total fisheries (Table 5) did not differ significantly between the 6 years examined (ANOVA; $0.05 < F < 1.0$, for all cases $P > 0.5$, d.f. = 9, 50).

The mean catch weights and densities of the primarily pelagic, primarily demersal and total fisheries over the 1982–1987 period, however, all differed significantly between the ten subareas (ANOVA; $37.6 < F < 149.3$, for all cases $P < 0.001$, d.f. = 9, 50). The application of Fisher's LSD test indicated that for all fisheries these parameters generally were significantly ($P < 0.05$) higher in subareas 10, 13 and 14 and lower in subareas 15 to 18.

The mean number of species comprising the catch and the mean eveness, richness and diversity of the pelagic, demersal and total fisheries over the 1982–1987 period all differed significantly between the ten subareas (ANOVA; $3.3 < F < 40.9$, for all cases $P < 0.01$, d.f. = 9, 50). The application of Fisher's LSD test indicated that for all three fisheries the mean number of species was generally significantly ($P < 0.05$) higher in subareas 8, 10, 13, 14 and 15, and lower in subarea 11; while the mean eveness, richness and diversity were all significantly ($P < 0.05$) higher in subareas 10, 15 and 18, and lower in subarea 11.

The following significant regressions were found between the log-transformed catch weights (W) and the number of species (N) comprising the catch for each subarea/year combination over the 1982–1987 period (Fig. 2).

Total fisheries: $\mathrm{Ln}\,W = 2.73 + 0.10N$, $r^2 = 0.85$, $n = 60$, $P < 0.001$

Demersal fisheries: $\mathrm{Ln}\,W = 1.56 + 0.14N$, $r^2 = 0.83$, $n = 60$, $P < 0.001$

Pelagic fisheries: $\mathrm{Ln}\,W = 2.38 + 0.44N$, $r^2 = 0.62$, $n = 60$, $P < 0.001$

Significant regressions with positive slopes were also found between the log-transformed catch weights (pelagic, demersal and total fisheries) and the different diversity indices for each subarea/year combination over the 1982–1987 period, with the exception of eveness in the case of the total and pelagic fisheries ($r^2 < 0.05$, $P > 0.05$), and richness in the case of the pelagic fisheries ($r^2 < 0.001$), but in all cases the r^2 values were much lower ($r^2 < 0.36$, $P < 0.001$) than those for the number of species.

The classification of all species from both main fisheries combined for each subarea/year combination (Fig. 3(a)) indicated that, at the 50% (Bray-Curtis) similarity level, the 10 subareas fall into three main groups: Group I (subareas 11, 12, 13 and 14); Group II (subareas 8, 10 and 15); and Group III (subareas 16, 17 and 18), representing the northern, central and southern Aegean Sea regions, respectively. The results of the ordination (MDS) of these subarea/year combinations (Fig. 3(b)) agree with the above pattern. For both analyses, the only exception is subarea 12 for 1986 (case 44 in Fig. 3), which overlaps with the subarea/year combinations of Group II. The remarkable latitudinal conformity with respect to the geographical relationships of the different subareas (Fig. 3(b)), with the exception of subarea 11, within the Aegean Sea as a whole is clearly illustrated by the significant correlation between the mean positions of each of

Table 3
Mean annual commercial catches, in tonnes, or primarily demersal species from the ten fishing subareas (S8 through S18; Fig. 1) in Greek Aegean waters, and total catches and percentages by species (or groups of species) over the period 1982–1987

Species common name[a]	Fishing subarea										Total	Percentage
	S8 1	S10 2	S11 3	S12 4	S13 5	S14 6	S15 7	S16 8	S17 9	S18 10		
Fishes												
Pickerel	975	542	8	193	206	248	495	868	1265	592	5392	16.0
Hake	330	295	40	201	710	653	168	13	78	71	2558	7.6
Grey mullets	15	204	2	80	1416	277	32	4	4	2	2036	6.1
Striped red mullet	143	249	1	79	135	172	97	165	384	151	1577	4.7
Red mullet	147	235	4	98	406	294	100	85	45	65	1479	4.4
Soles	25	53	0	13	590	301	7	7	3	5	1006	3.0
Blue whiting	27	136	0	38	442	240	104	0	4	6	997	3.0
Gurnards	62	80	1	15	31	227	32	55	155	18	676	2.0
Saddled bream	57	32	1	52	74	192	16	39	205	7	674	2.0
Red pandora	77	194	1	52	16	30	38	53	83	24	569	1.7
Anglerfishes	19	41	1	1	413	50	23	0	3	1	553	1.6
Scorpionfishes	65	33	0	13	24	98	57	80	95	65	529	1.6
Thornback ray	7	0	0	5	184	239	9	1	3	3	452	1.3
Blotched pickerel	78	42	1	23	59	30	49	38	36	7	364	1.1
Thick blotched pickerel	8	83	1	34	108	84	34	1	1	8	363	1.1
Smoothhounds	21	4	0	40	68	158	41	2	4	17	354	1.1
White sea bream	33	23	0	17	37	50	17	28	110	28	343	1.0
Whiting	5	1	0	0	181	88	13	2	0	0	290	0.9
Gilthead sea bream	3	157	0	44	29	21	1	17	2	0	275	0.8
Black sea bream	19	27	0	17	36	12	39	32	81	7	270	0.8
Annular sea bream	9	20	1	7	172	33	6	2	1	1	252	0.7
Common sea bream	16	7	0	6	16	10	59	16	43	48	221	0.7
Tub fish	17	81	1	13	33	7	6	10	2	2	171	0.5
Dogfishes	2	0	0	2	4	26	79	1	1	50	165	0.5
Stone bass	10	6	0	8	4	8	28	3	9	79	154	0.5

Salema	18	7	0	3	36	58	13	1	10	2	148	0.4
Common dentex	11	16	0	3	30	21	15	14	26	8	143	0.4
European sea bass	2	18	0	3	60	6	1	2	3	1	96	0.3
Rays	24	7	0	12	4	21	14	1	2	1	86	0.3
Comber	17	5	0	1	1	2	7	17	19	13	82	0.2
Brill	2	58	0	2	5	6	1	1	1	0	76	0.2
Large-eye dentex	22	6	0	2	3	9	13	3	6	3	67	0.2
John dory	15	10	0	2	10	8	7	2	6	5	64	0.2
Dusky grouper	4	1	0	1	5	5	4	6	3	30	58	0.2
Greater amberjack	9	6	0	3	4	3	4	3	3	4	39	0.1
Rockfish	2	10	0	5	9	6	1	2	0	0	35	0.1
Guitarfishes	0	0	0	0	18	13	3	0	0	0	35	0.1
Shi drum	1	4	0	2	14	11	0	2	1	0	34	0.1
White grouper	9	1	0	4	1	1	3	2	2	4	28	0.1
European eel	3	0	0	1	7	3	0	0	0	1	15	0.0
Other fish	218	326	10	159	3305	577	282	331	1080	182	6470	19.2
Cephalopoda												
Cuttlefish	14	24	0	5	427	199	45	4	8	38	765	2.3
Poulpes	22	15	0	3	415	139	15	3	7	24	644	1.9
Common squid	24	33	0	5	120	116	53	35	47	21	456	1.4
Octopus	21	19	0	7	76	242	14	10	11	25	425	1.3
Flying squid	60	13	0	10	54	41	28	1	6	14	226	0.7
Crustaceans												
Crayfish	51	49	1	28	376	275	65	2	9	1	855	2.5
Shrimps	51	2	0	12	421	87	75	3	10	108	767	2.3
Common prawn	3	1	0	1	88	33	12	0	1	33	171	0.5
Lobsters	9	11	0	24	16	10	23	2	15	3	113	0.3
Crabs	2	1	0	0	16	5	0	0	0	0	24	0.1
Total demersal	2785	3185	78	1347	10918	5442	2250	1969	3891	1779	33644	100
Demersal (%)	8.3	9.4	0.2	4.0	32.4	16.2	6.7	5.9	11.6	5.3	40.4[b]	

[a]For scientific names see Table 1.
[b]Percentage of the total Aegean catch which is attributed to primarily demersal species.
Numbers 1–10 represent the code numbers used for multivariate analyses.
Species are listed in decreasing order of total catch.

Table 4
Mean annual commercial catches, in tonnes, of primarily pelagic species from the ten fishing subareas (S8 through S18; Fig. 1) in Greek Aegean Sea waters, and total catches and percentages by species (or groups of species) over the period 1982–1987

Species common name[a]	Fishing subarrea										Total	Percentage
	S8 1	S10 2	S11 3	S12 4	S13 5	S14 6	S15 7	S16 8	S17 9	S18 10		
Fishes												
Anchovy	1387	1006	334	2408	7817	3304	129	99	20	1	16506	33.2
Sardine	1672	680	32	741	3079	2983	765	14	99	35	10100	20.3
Horse mackerels	2343	689	8	431	1372	868	482	42	939	305	7479	15.1
Bogue	1148	726	11	408	537	438	1055	776	1173	423	6696	13.5
Chub mackerel	71	60	1	156	519	533	791	518	111	7	2766	5.6
Blufin tuna	59	6	0	135	498	775	36	3	253	3	1770	3.6
Bonito	925	28	1	18	15	11	54	148	57	53	1311	2.6
Jack mackerel	162	240	17	312	181	198	86	0	29	6	1232	2.5
Swordfish	82	11	0	24	6	10	5	296	114	208	757	1.5
Mackerel	38	12	0	22	167	141	16	1	9	1	406	0.8
Garfishes	84	13	0	3	26	7	121	4	13	0	271	0.5
Bluefish	6	4	0	2	80	90	6	2	0	2	193	0.4
Skipjack	23	5	0	4	1	1	29	9	10	37	117	0.2
Gilt ssardines	45	3	0	0	5	1	0	0	4	13	71	0.1
Sprat	9	2	0	0	2	0	9	0	0	0	23	<0.1
Total pelagic	8054	3485	405	4665	14305	9361	3584	1915	2831	1092	49699	100
Pelagic (%)	16.2	7.0	0.8	9.4	28.8	18.8	7.2	3.9	5.7	2.2	59.6[b]	
Grand total	10839	6670	483	6013	25223	14803	5834	3884	6723	2871	83343	
Grand total (%)	13.0	8.0	0.6	7.2	30.3	17.8	7.0	4.6	8.1	3.4	100	

[a]For scientific names see Table 1.
[b]Percentage of the total Aegean catch which is attributed to primarily pelagic species.
Grand total represents mean catch of primarily demersal and primarily pelagic species combined. Numbers 1–10 represent the code numbers used for multivariate analyses. Species are listed in decreasing order of total catch.

the nine site groups (excluding subarea 11) within the ordination with the latitudes of the mid points of the nine fishing statistical subareas ($r=0.87$, $P<0.01$). The correlation between these mean positions and the longitudes of the mid points of these subareas, however, was not significant ($r=0.5$, $P>0.1$).

When the primarily pelagic species only from the total species array are considered alone, there are again the same three main groupings of subareas, which in this case separate at the 53% similarity level (Fig. 4): Group I (subareas 11, 12, 13 and 14; northern Aegean); Group II (subareas 8, 10 and 15; central Aegean); and Group III (subareas 16, 17 and 18; southern Aegean). The only exceptions are subarea 12 for 1986 (case 44 in Fig. 4) and subarea 16 for 1986 (case 48 in Fig. 4), which overlap with the subarea/year combinations of Group II.

When the primarily demersal species only from the total species array are considered alone, a different picture prevails, here involving two main groupings separated at the 50% similarity level (Fig. 5). In this case subareas 13 and 14 form a northern grouping (Group I) whereas subareas 8, 10, 12 and 15 are associated with subareas 16, 17 and 18 and form a southern grouping (Group II; Fig. 5). In the latter group the only exceptions are subarea 10 for 1986 and 1987 (cases 42 and 52) which form one minor group (Group III) and subarea 11 for the years 1983, 1984 and 1987 (cases 13, 23 and 53) which form a second minor group (Group IV). Cases 44 (subarea 12 for the year 1986), associated with Group III in cluster analysis (Fig. 5(a)), and 54 (subarea 12 for the year 1987), associated with Group I (Fig. 5), were probably misclassified by the cluster analysis. Hence, for the purposes of the present study these two cases were considered to belong to the southern Group II.

In all cases, the resulting stress values for the two-dimensional plots (Figs. 3, 4 and 5) were low (demersal = 0.14, pelagic = 0.04, total = 0.04), implying the adequacy of the MDS representations in these two dimensions.

The species compositions of the mean catches of the groups identified by the multivariate analyses also differ considerably (Tables 6 and 7). With respect to the primarily demersal fisheries, the mean catch of the northern group was dominated by grey mullets, hake and soles, representing 10.3%, 8.3% and 5.4% of the mean catch, respectively (Table 6). The mean catch of the southern group (including the minor Groups III and IV; Fig. 5(b)) was dominated by pickerel, representing 28.6% of the mean catch, followed by striped red mullet (7.3%), hake (6.9%) and red mullet (4.5%) (Table 6).

With respect to the primarily pelagic fisheries, the mean catch of the northern group was dominated by anchovy and sardine, representing 48.2% and 23.8% of the mean catch, respectively, followed by horse mackerels (9.3%) (Table 7). The mean catch of the central group was dominated by horse mackerel, sardine, bogue and anchovy, representing 23.2%, 20.6%, 19.4% and 16.7% of the mean catch, respectively, followed by bonito (6.7%) and chub mackerel (6.1%) (Table 7). Finally, the mean catch of the southern group was dominated by bogue and horse mackerels, representing 40.6% and 22.0% of the mean catch, respectively, followed by chub mackerel (10.9%) and swordfish (10.6%) (Table 7).

When the pelagic and demersal fisheries are combined (analytic data not

Table 5
Annual catch weight (W in tonnes), number of species (N), richness (R), Shannon-Wieiner diversity (D), and evenness (E) of the primarily demersal, primarily pelagic and total fisheries in the tten fishing subareas (S; 8, 10 to 18: Fig. 1) in Greek Aegean Sea waters over the period 1982–1987

Year	S	Demersal fisheries					Pelagic fisheries					Total fisheries				
		W	N	R	D	E	W	N	R	D	E	W	N	R	D	E
1982	8	3098	48	5.8	2.5	0.7	5870	15	1.6	2.0	0.7	8968	63	6.8	2.8	0.7
1982	10	2744	50	6.2	2.6	0.7	2660	14	1.6	1.7	0.7	5404	64	7.3	2.8	0.7
1982	11	90	32	6.9	2.6	0.7	927	10	1.3	0.5	0.2	1017	42	5.9	1.0	0.3
1982	12	1049	46	6.5	2.6	0.7	3928	14	1.6	1.5	0.6	4977	60	6.9	2.3	0.6
1982	13	10083	51	5.4	2.7	0.7	14007	15	1.5	1.5	0.5	24090	66	6.4	2.7	0.6
1982	14	4056	51	6.0	3.3	0.8	9768	14	1.4	1.6	0.6	13824	65	6.7	2.7	0.6
1982	15	1996	48	6.2	2.8	0.7	2105	14	1.7	1.8	0.7	4101	62	7.3	3.0	0.7
1982	16	1567	43	5.7	2.1	0.6	2551	13	1.5	1.3	0.5	4118	56	6.6	2.3	0.6
1982	17	3139	45	5.5	2.2	0.6	2425	13	1.5	1.5	0.6	5564	58	6.6	2.5	0.6
1982	18	1115	49	6.8	2.5	0.7	596	12	1.7	1.6	0.6	1711	61	8.1	2.9	0.7
1983	8	2897	49	6.0	2.6	0.7	6518	15	1.6	1.8	0.7	9415	64	6.9	2.7	0.7
1983	10	2137	48	6.1	2.5	0.7	2655	12	1.4	1.6	0.6	4792	60	7.0	2.7	0.7
1983	11	36	18	4.7	1.6	0.5	91	6	1.1	0.9	0.5	127	24	4.7	1.8	0.6
1983	12	1116	43	6.0	2.8	0.8	4602	10	1.1	1.4	0.6	5718	53	6.0	2.2	0.6
1983	13	11122	51	5.4	2.6	0.7	11725	15	1.5	1.6	0.6	22847	66	6.5	2.8	0.7
1983	14	3668	51	6.1	3.2	0.8	6822	13	1.4	1.8	0.7	10490	64	6.8	2.9	0.7
1983	15	2379	48	6.0	3.0	0.8	3275	14	1.6	1.9	0.7	5654	62	7.1	3.0	0.7
1983	16	2194	41	5.2	2.1	0.6	2882	12	1.4	1.3	0.5	5076	53	6.1	2.4	0.6
1983	17	3055	44	5.4	2.0	0.5	2018	13	1.6	1.5	0.6	5073	57	6.6	2.5	0.6
1983	18	1881	44	5.7	2.5	0.7	836	9	1.2	1.6	0.7	2717	53	6.6	2.8	0.7
1984	8	2736	51	6.3	2.6	0.7	9407	15	1.5	1.8	0.7	12143	66	6.9	2.5	0.6
1984	10	2081	48	6.2	2.6	0.7	2605	12	1.4	1.8	0.7	4686	60	7.0	2.8	0.7
1984	11	62	10	2.2	1.1	0.5	75	8	1.6	1.4	0.7	137	18	3.5	2.0	0.7
1984	12	1207	47	6.5	2.8	0.7	5712	13	1.4	1.3	0.5	6919	60	6.7	2.1	0.5
1984	13	11220	51	5.4	2.5	0.6	13235	13	1.3	1.4	0.6	24455	64	6.2	2.6	0.6
1984	14	4834	51	5.9	3.2	0.8	7428	13	1.3	1.7	0.7	12262	64	6.7	3.0	0.7
1984	15	2182	47	6.0	3.1	0.8	3477	14	1.6	1.6	0.6	5659	61	6.9	2.8	0.7
1984	16	2085	44	5.6	2.3	0.6	1443	14	1.8	1.5	0.6	3528	58	7.0	2.6	0.6
1984	17	3411	47	5.7	2.1	0.6	2112	12	1.4	1.7	0.7	5523	59	6.7	2.6	0.6
1984	18	1883	42	5.4	2.5	0.7	899	12	1.6	1.4	0.6	2782	54	6.7	2.8	0.7
1985	8	2436	51	6.4	2.6	0.7	9939	15	1.5	1.7	0.6	12375	66	6.9	2.4	0.6
1985	10	2388	47	5.9	2.8	0.7	3560	15	1.7	1.7	0.6	5948	62	7.0	2.8	0.7
1985	11	60	19	4.4	1.9	0.6	136	7	1.2	1.3	0.7	196	26	4.7	2.2	0.7
1985	12	1891	46	6.0	2.8	0.7	7534	14	1.5	1.6	0.6	9425	60	6.4	2.3	0.6
1985	13	10477	51	5.4	2.6	0.7	11334	14	1.4	1.4	0.5	21811	65	6.4	2.7	0.6
1985	14	5846	50	5.6	3.2	0.8	9904	15	1.5	1.6	0.6	15750	65	6.6	2.8	0.7
1985	15	2211	50	6.4	3.2	0.8	4898	15	1.6	1.8	0.7	7109	65	7.2	2.9	0.7
1985	16	2326	43	5.4	2.2	0.6	1766	15	1.9	1.4	0.5	4092	58	6.9	2.5	0.6
1985	17	3943	46	5.4	2.1	0.5	2707	14	1.6	1.4	0.5	6650	60	6.7	2.5	0.6
1985	18	1738	46	6.0	2.7	0.7	1036	14	1.9	1.5	0.6	2774	60	7.4	2.9	0.7
1986	8	2192	49	6.2	2.7	0.7	9761	15	1.5	1.8	0.6	11953	64	6.7	2.4	0.6
1986	10	5270	51	5.8	2.7	0.7	5153	15	1.6	1.6	0.6	10423	66	7.0	2.9	0.7
1986	11	73	23	5.1	2.1	0.7	1079	8	1.0	0.6	0.3	1152	31	4.3	0.9	0.3
1986	12	2085	46	5.9	2.8	0.7	2786	12	1.4	1.8	0.7	4871	58	6.7	2.9	0.7

Year	S	Demersal fisheries					Pelagic fisheries					Total fisheries				
		W	*N*	*R*	*D*	*E*	*W*	*N*	*R*	*D*	*E*	*W*	*N*	*R*	*D*	*E*
1986	13	13019	51	5.3	2.6	0.7	15652	12	1.1	1.4	0.6	28671	63	6.0	2.6	0.6
1986	14	7186	51	5.6	3.1	0.8	8291	14	1.4	1.7	0.7	15477	65	6.6	3.1	0.7
1986	15	2390	48	6.0	3.0	0.8	3888	14	1.6	1.7	0.6	6278	62	7.0	2.9	0.7
1986	16	1851	40	5.2	2.0	0.5	1840	12	1.5	1.5	0.6	3691	52	6.2	2.4	0.6
1986	17	4606	45	5.2	2.2	0.6	3908	13	1.5	1.4	0.5	8514	58	6.3	2.5	0.6
1986	18	1528	45	6.0	2.8	0.7	1028	10	1.3	1.6	0.7	2556	55	6.9	3.0	0.7
1987	8	3215	50	6.1	2.7	0.7	6791	15	1.6	1.8	0.7	10006	65	6.9	2.7	0.7
1987	10	4360	48	5.6	3.0	0.8	4245	14	1.6	1.7	0.6	8605	62	6.7	3.1	0.7
1987	11	98	23	4.8	1.1	0.4	102	8	1.5	1.0	0.5	200	31	5.7	1.8	0.5
1987	12	611	41	6.2	3.3	0.9	3398	11	1.2	1.3	0.6	4009	52	6.1	2.1	0.5
1987	13	9444	51	5.5	3.0	0.8	19840	15	1.4	1.2	0.4	29284	66	6.3	2.4	0.6
1987	14	6927	50	5.5	3.1	0.8	13914	14	1.4	1.6	0.6	20841	64	6.3	2.7	0.7
1987	15	2217	48	6.1	3.1	0.8	3820	15	1.7	1.8	0.7	6037	63	7.1	2.9	0.7
1987	16	1684	42	5.5	1.8	0.5	976	11	1.5	1.4	0.6	2660	53	6.6	2.4	0.6
1987	17	5066	46	5.3	2.2	0.6	3787	14	1.6	1.6	0.6	8853	60	6.5	2.7	0.6
1987	18	2403	45	5.7	2.7	0.7	2128	13	1.6	1.4	0.5	4531	58	6.8	2.8	0.7

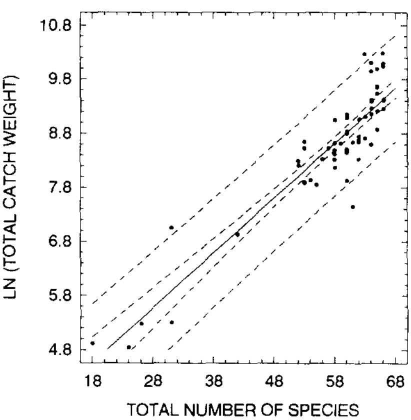
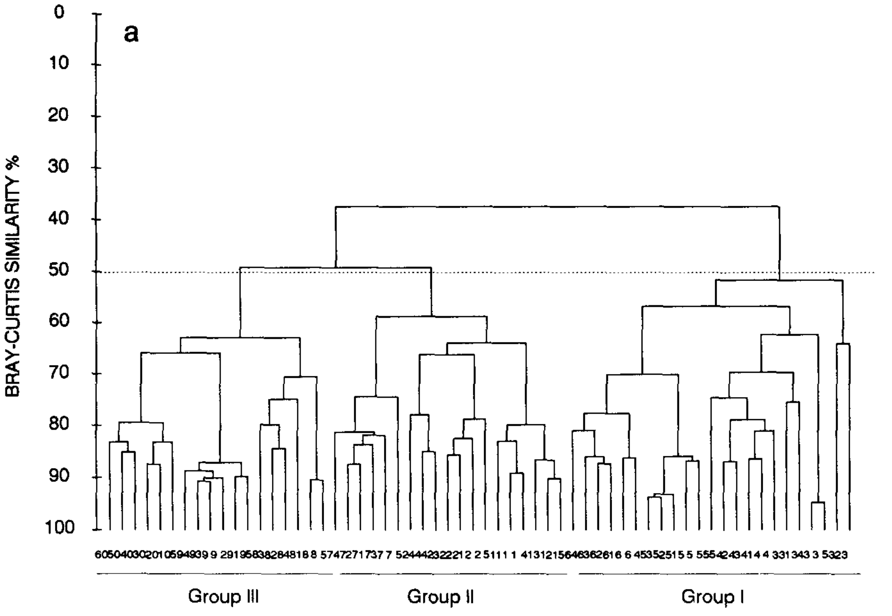


Fig. 2. Regression line (continuous) between the total number of species and log catch weight, in tonnes, in the 60 subarea/year combinations, together with the 95% and 99% confidence intervals (dotted lines).

shown), the mean catch of the northern group was dominated by anchovy and sardine, representing 29.8% and 14.7% of the mean catch, respectively, followed by horse mackerels (5.8%), grey mullets (3.8%) and hake (3.4%). The mean catch of the central group was dominated by horse mackerels, sardine, bogue and anchovy, representing 15.1%, 13.4%, 12.6% and 10.8% of the mean catch, respectively, followed by pickerel (8.6%), bonito (4.3%), chub mackerel (4.0%) and hake (3.4%). Finally, the mean catch of the southern group was dominated by pickerel and bogue, representing 20.2% and 17.6% of the mean total catch, re-



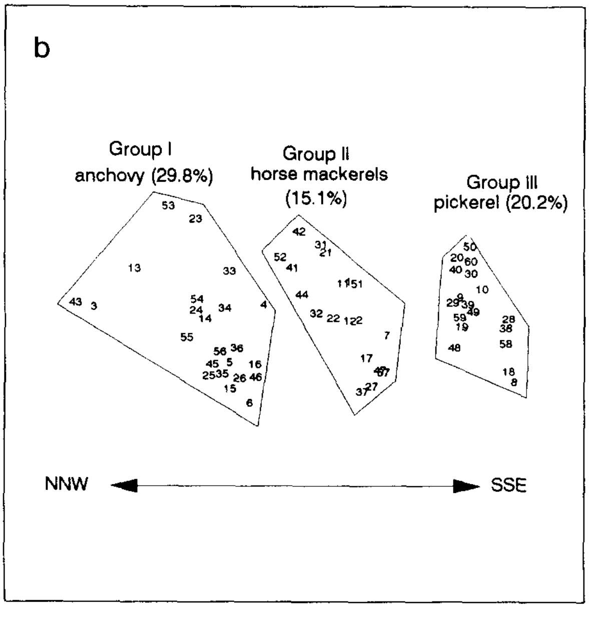


Fig. 3. (a) Dendrogram for group-average clustering. (b) Multidimensional scaling (MDS) ordination, based on Bray-Curtis similarities between standardized catch weights, of all species combined from the ten Aegean fishing subareas with six replicates (years) at each subarea. For the MDS plot, orientation and scale were arbitrary and the stress coefficient was 0.04. The dominant species for each group are also shown. Codes: Subarea/year combinations 1, 11, 21, 31, 41 and 51 correspond to subarea 8 for the years 1982 to 1987, respectively; subarea/year combination 2, 12, 22, 32, 42 and 52 correspond to subarea 10 for the years 1982 to 1987, respectively, etc.

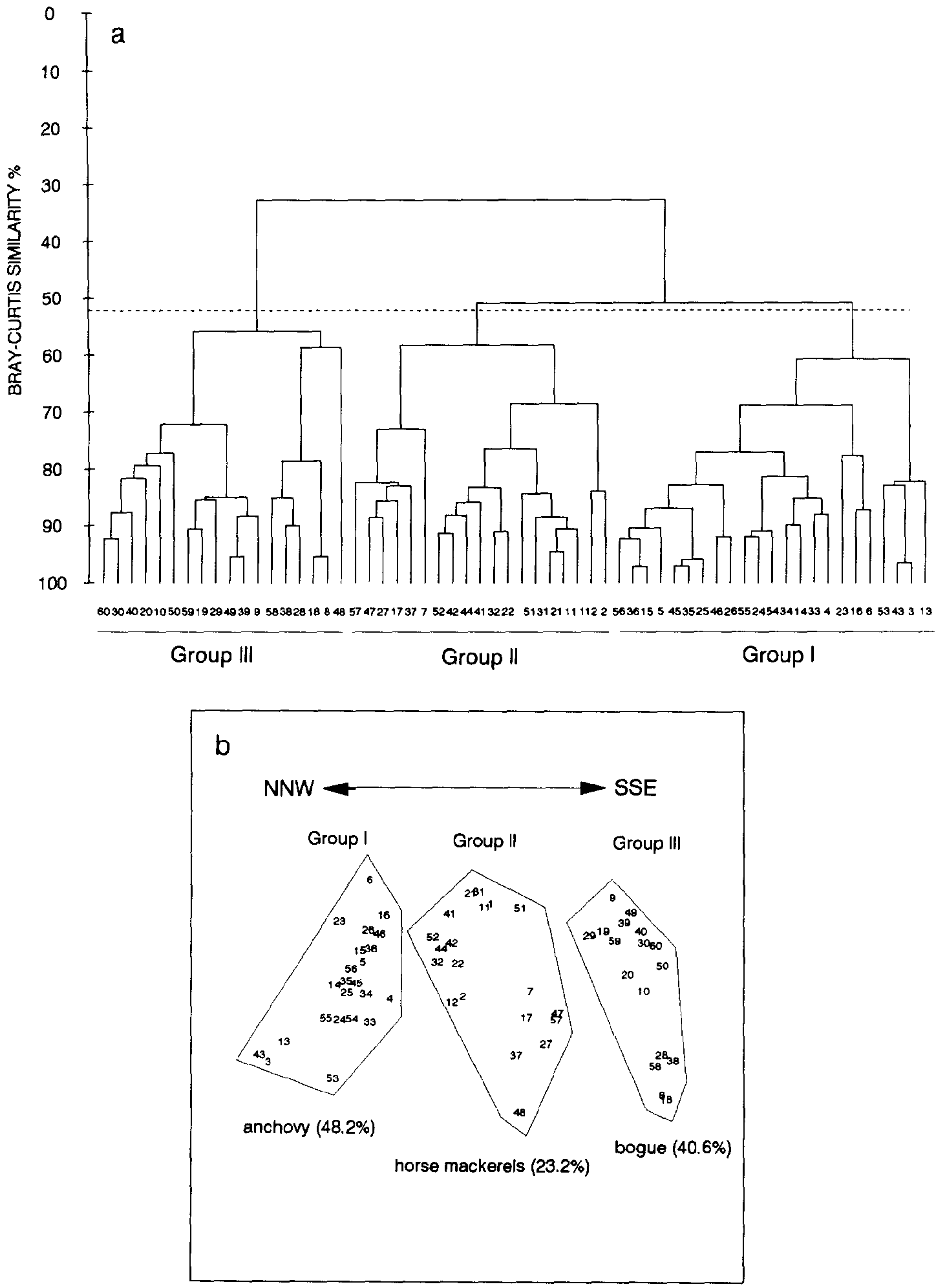


Fig. 4. (a) Dendrogram for group-average clustering. (b) Multidimensional scaling (MDS) ordination, based on Bray-Curtis similarities between standardized catch weights, of primarily pelagic species from the 10 Aegean fishing subareas with six replicates (years) at each subarea. For the MDS plot, orientation and scale were arbitrary and the stress coefficient was 0.04. The dominant species for each group are also shown. Codes as in Fig. 3.

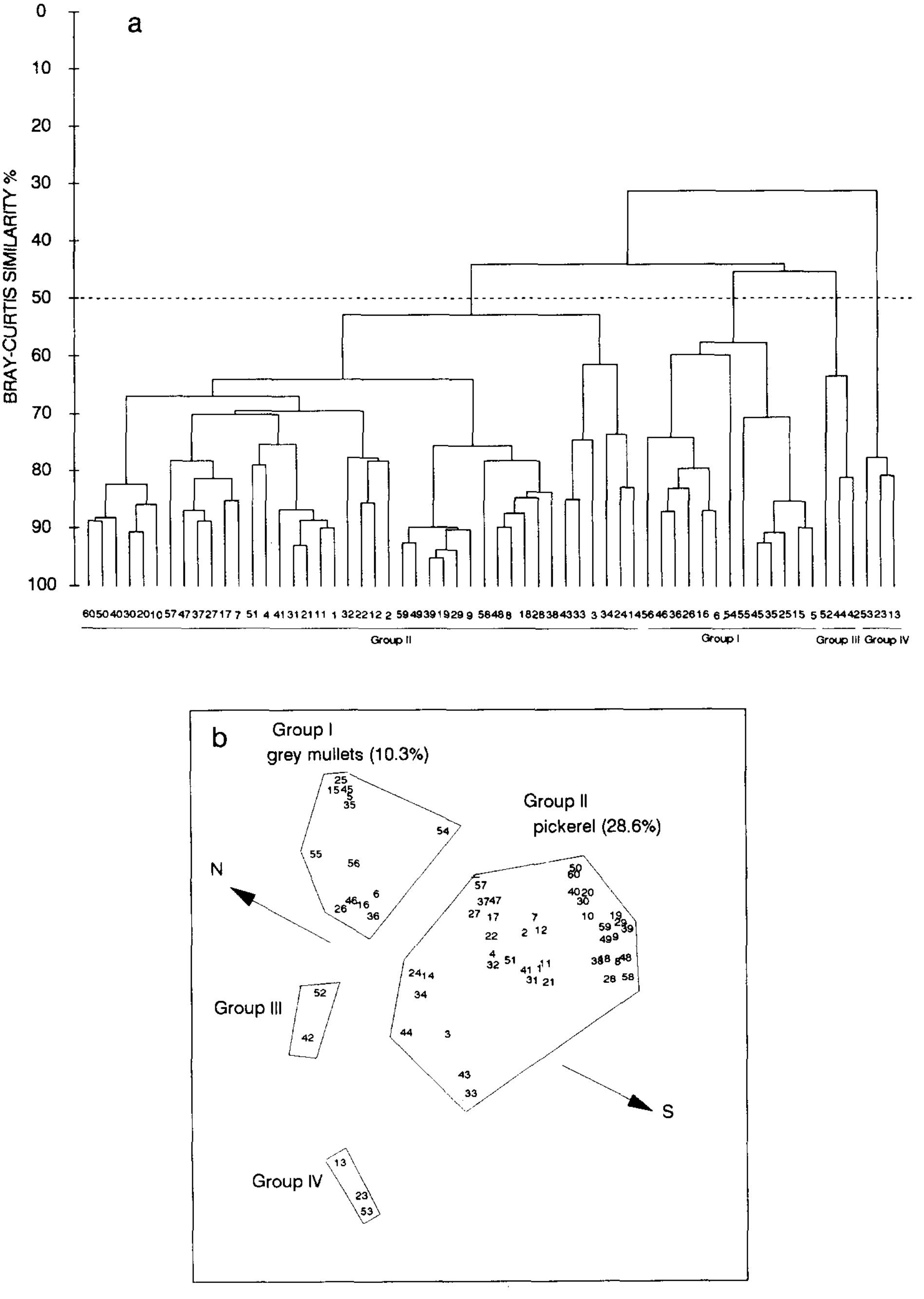


Fig. 5. (a) Dendrogram for group-average clustering. (b) Multidimensional scaling (MDS) ordination, based on Bray-Curtis similarities between standardized catch weights, of primarily demersal species from the ten Aegean fishing subareas with six replicates (years) at each subarea. For the MDS plot, orientation and scale were arbitrary and the stress coefficient was 0.14. The dominant species for the two main groups (I and II) are also shown. Codes as in Fig. 3.

Table 6
Mean commercial catches, in tonnes, and percentages of the primarily demersal species over the period 1982–1987 for each of the two groups of fishing subareas identified by multivariate analysis. (Here Group II also includes the minor Groups III and IV; see Fig. 5 and text)

Species common name	Southern Group II S.8, 10, 12, 15–18		Species common name	Northern Group I S.13, 14	
	Catch	Percentage		Catch	Percentage
Pickerel	4938	28.6	Grey mullets	1693	10.3
Striped red mullet	1269	7.3	Hake	1363	8.3
Hake	1195	6.9	Soles	891	5.4
Red mullet	779	4.5	Red mullet	700	4.3
Red pandora	523	3.0	Blue whiting	682	4.2
Gurnards	418	2.4	Crayfish	651	4.0
Scorpionfishes	407	2.4	Cuttlefish	626	3.8
Saddled bream	408	2.0	Poulpes	554	3.4
Grey mullets	343	2.0	Shrimps	508	3.1
Others	7004	40.5	Anglerfishes	463	2.8
			Pickerel	454	2.8
			Thornback ray	423	2.6
			Others	7352	44.9
Total	17284			16360	
Total (%)	51.4			48.6	
Mean density	0.3792			1.4120	
95% CI	0.26–0.50			1.18–1.64	

The mean densities (catch per unit of continental shelf area, in tonnes/km^2) of the demersal species and the 95% confidence intervals (CI) of the mean densities for each of the two groups of fishing subareas are also shown.

spectively, followed by horse mackerels (9.5%), striped red mullet (5.2%), chub mackerel (4.7%) and swordfish (4.6%).

Figure 6 shows the MDS configurations of the primarily pelagic and primarily demersal fisheries, as in Figs. 4(b) and 5(b), with superimposed symbols proportional to the values of catch density for each subarea/year combination. In general, catch density increases from south to north. The mean catch densities of the subarea/year combinations of the groups identified by multivariate analyses differed significantly for all three fisheries (pelagic: ANOVA, $F=45.4$, $P<0.001$, d.f.$=2$, 57; total: ANOVA, $F=30.4$, $P<0.001$, d.f.$=2$, 57; demersal: t-test, $t=-6.1$, $P<0.01$). Mean catch densities were significantly ($P<0.001$) higher in the northern and central groups, for the pelagic and total fisheries, and in the northern group, for the demersal fishery, than in the southern groups (LSD results in Table 7).

The K-dominance curves (Fig. 7) display the patterns observed from the univariate and multivariate analyses. In the cases of the pelagic and total fisheries, dominance is more pronounced for the northern Aegean group, because of the high participation of anchovy (Table 7), and less pronounced in the central Aegean group (Fig. 7). In contrast, for the demersal fishery dominance is more pro-

Table 7
Mean commercial catches, in tonnes, and percentages of the primarily pelagic species over the period 1982–1987 for each of the three groups of fishing subareas identified by multivariate analysis (see Fig. 4)

Species common name	Southern Group III S.16, 17, 18		Central Group II S.8, 10, 15		Northern Group I S.11–14	
	Catch	Percentage	Catch	Percentage	Catch	Percentage
Anchovy	120	2.1	2522	16.7	13863	48.2
Bogue	2372	40.6	2930	19.4	1395	4.9
Bluefish	4	0.1	16	0.1	173	0.6
Garfish	17	0.3	217	1.4	36	0.1
Chub mackerel	636	10.9	922	6.1	1209	4.2
Swordfish	618	10.6	98	0.6	41	0.1
Bonito	258	4.4	1008	6.7	45	0.2
Sprat	0	0.0	20	0.1	3	0.0
Skipjack	55	0.9	56	0.4	6	0.0
Jack mackerel	35	0.6	489	3.2	708	2.5
Sardine	148	2.5	3117	20.6	6835	23.8
Horse mackerels	1286	22.0	3514	23.2	2679	9.3
Mackerel	11	0.2	65	0.4	329	1.1
Bluefin tuna	259	4.4	101	0.7	1409	4.9
Gilt sardines	17	0.3	48	0.3	6	0.0
Total catch	5839		15123		28736	
Total (%)	11.7		30.4		57.9	
Mean density	0.0465		(0.4934)		(0.6938)	
95% CI	0–0.22		0.32–0.67		0.54–0.84	
Mean density[a]	0.1069		(0.8358)		(1.0679)	
95% CI	0–0.40		0.54–1.13		0.81–1.32	

[a]Pelagic and demersal fisheries combined.
The mean density (catch per unit of water area, in tonnes km^{-2}) of the pelagic species and of all species combined, the 95% confidence intervals (CI) of the mean densities for each of the three groups of fishing subareas and the results of Fischer's LSD test (mean densities in parentheses do not differ significantly, $P > 0.05$) are also shown.

nounced in the southern Aegean group, because of the high participation of pickerel (Table 6), and less pronounced in the northern Aegean group (Fig. 7).

4. Discussion

Fishery faunal units differ from their natural unfished counterparts in terms of both fish size and abundance and relative species composition because of fishing gear selectivity and discarding practices (Murawski et al., 1983). Both multivariate (e.g. cluster analysis: Murawski et al., 1983; Stergiou, 1988; non-metric multidimensional scaling: Stergiou, 1988, 1989) and univariate techniques (e.g. diversity indices: Smetanin et al., 1984), which have been widely used in various community studies, can also be applied to the qualitative/quantitative analysis

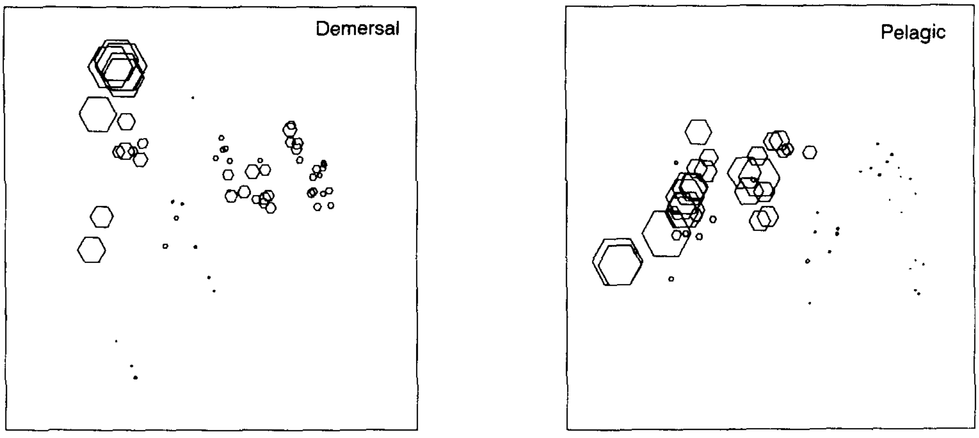


Fig. 6. Multidimensional scaling ordination of primarily pelagic and primarily demersal species, exactly as in Figs. 4(b) and 5(b), with superimposed symbols of linear dimensions proportional to the values of catch weight per unit of water area (smallest symbol represents 0.0146 t km^{-2}, largest 1.6033 t km^{-2}) and catch weight per unit of continental shelf area (smallest symbol represents 0.0535 t km^{-2}, largest 2.5578 t km^{-2}), respectively.

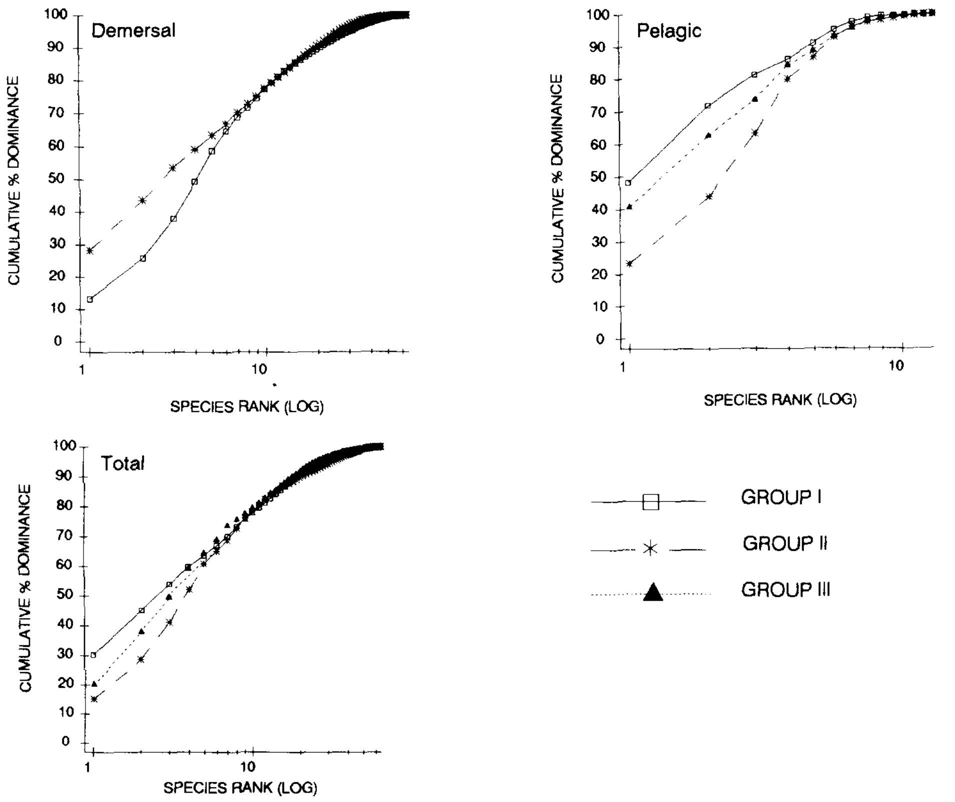


Fig. 7. *K*-dominance curves for the groupings identified by multivariate analyses for the primarily demersal, primarily pelagic and total fisheries.

of commercial fishery catch data. Dominance curves (e.g. Lambshead et al., 1983) are also extensively used in community studies, mainly for pollution monitoring (e.g. Gray et al., 1988).

Indeed, the results of the analysis using the various statistical techniques which have been applied here are in close agreement, complement each other, and all suggest that the ten subareas may be generally grouped into few geographical clusters (two for the primarily demersal fishery and three for the primarily pelagic and total fisheries), which differ considerably from each other in terms of species composition, species diversity and catch density. The main factors which may contribute to such a geographical differentiation could be: (a) the gradient in eutrophy, river runoff, temperature and salinity of Aegean Sea waters along a NNW to SSE axis, and (b) the differences in extent of the continental shelf within these areas of the Aegean Sea. These factors are discussed below.

The eastern Mediterranean Sea is known to be one of the most oligotrophic marine regions of the world (Friligos 1980, 1987). In the Aegean Sea area, annual gross primary production in the outer part of subarea 8 and in the southern part of subarea 10 amounted to 64 and 30 gC m^{-2}, respectively, with the latter figure being among the lowest recorded for the Mediterranean Sea (Becacos-Kontos, 1968, 1977). Secondary production in the outer part of subarea 8 (0.12–0.19 gC m^{-3} $year^{-1}$) is among the lowest recorded for a marine area in the world literature (Christou, 1991). However, within this generally oligotrophic environment relatively eutrophic areas do exist. Indeed, subareas 12, 13 and 14 are all characterized by higher nutrient and plant pigment concentrations as compared with the remaining subareas (Stergiou and Georgopoulos, 1993). Subareas 12, 13 and 14 are all influenced by nutrient inputs from outflowing Black Sea waters. These waters enter the Aegean Sea from the Dardanelles Strait and are colder, less saline and much richer in nutrients than the waters of Levantine origin that enter the Aegean Sea mainly from the eastern straits of the Cretan Arc (Theocharis and Georgopoulos, 1993; Georgopoulos et al., 1989). Freshwater runoff is also relatively important along the northern rim of the Aegean (17, 657x10^6 m^3 $year^{-1}$) as compared with the remaining part of the Greek Aegean Sea (< 1000 m^3 $year^{-1}$; Therianos, 1974).

In addition, in the south–eastern Mediterranean Sea the majority of the plankton biomass and production is in the picoplankton size fraction, a fact which presumably increases the number of trophic levels and, hence, may limit the potential production at higher trophic levels (Walline, 1987; Azov, 1991), possibly resulting in a lower biomass of small pelagic fishes. Indeed, the pelagic catch densities decline from north to south (Table 7) and this is consistent with the fact that the density of small pelagic fishes along the northern rim of the Aegean Sea (subareas 13 and 14) is higher by an order of magnitude than those in subareas 12 and 15, as indicated by hydroacoustic surveys (Stergiou et al., 1993).

The salinity and temperature differences in the Aegean Sea may also be related to the geographical grouping of the ten fishing subareas. Hence, the lower salinity prevailing along the coasts of subareas 13 and 14, which are influenced by the Black Sea waters and river runoff, may explain the predominance of the relatively euryhaline grey mullets in the northern group of the demersal fishery (Group I, Table 6). In addition, the pelagic anchovy and horse mackerels and the demersal hake, which dominate the pelagic (Table 7) and demersal catches (Table 6) of the northern and central Aegean groups, respectively, are replaced by bogue and pickerel, respectively, in the southern Aegean group (Tables 6 and 7). Both bogue and pickerel are generally characterized by a more southern distribution (they are not found to the north of Portugal in Atlantic waters) as compared with anchovy, horse mackerels and hake (see Whitehead et al., 1984).

The difference observed in the groupings of the primarily pelagic (Fig. 4) and primarily demersal fisheries (Fig. 5) can be explained in terms of the extent of the continental shelf and the distribution of Black Sea waters in the Aegean Sea. The primarily pelagic species are mainly influenced by the distribution of Black Sea waters, the distribution of which generally coincides with that of the pelagic north Aegean group (subareas 11 to 14). Because the effect of the Black Sea waters is felt down to 50–70 m depth (Theocharis and Georgopoulos, 1993) and the continental shelf of subarea 12 is very narrow (Fig. 1), the northern group in the case of the demersal fisheries is restricted to subareas 13 and 14. It is worthy of mention that the Aegean Sea is generally separated into two areas with respect to the distribution of benthos (Peres, 1967): a northern part, to the north of a line connecting the islands of Euboia and Psara, which is characterized by cold-water fauna, as compared with a warmer water fauna in the southern part, to the south of this line. These two parts of the Aegean Sea generally coincide with the northern vs. southern groups identified in the case of the demersal fisheries (Fig. 5).

For both the pelagic and demersal fisheries and for all fisheries combined, each of the above groups varied little over time, with the primary exception of subarea 11, which was relatively diffuse in all three cases (Figs. 3, 4 and 5), and subarea 16 in 1986 in the case of the pelagic fisheries (case 48 in Fig. 4); and subareas 10 and 12 in the case of the demersal fisheries (Fig. 5). In addition, subarea 11 was characterized by lower species number, diversity, eveness and richness. With respect to subarea 16, the species composition of the mean pelagic catch over the years 1982–1985 and 1987 (bogue 42.4%, chub mackerel 30.5%, swordfish 13.3% and bonito 8.7%) differed considerably from that in 1986 (bogue 30.7%, anchovy 28.5% and swordfish 26.9%).

With respect to subarea 10, the species composition of the mean demersal catch over the years 1986–1987 (hake 12.9%, striped red mullet 9.5%, red pandora 8.3%, red mullet 8.3%, gilthead sea bream 8.1%, grey mullets 7.8%, pickerel 6.6% and blue whiting 6.2%) also differed considerably from that in 1982–1985 (pickerel 27.7%, red mullet 6.4%, striped red mullet 6.1%, hake 5.5% and grey mullets 4.9%). The same was also true of subarea 12, for which the species composition of the demersal catch in 1982 (pickerel 26.3%, hake 13.6%, blotched pickerel 6.0% and red mullet 5.5%) differed considerably from that in 1987 (pickerel 8.6%, hake 6.3%, grey mullets 6.8% and lobsters 6.6%) and from the mean catch in 1983–1986 (hake 16.0%, pickerel 12.9%, red mullet 8.2%, grey mullets 6.7% and striped red mullet 6.6%).

With respect to subarea 11, this is the only subarea out of the ten Aegean fishing subareas in which trawling has been disallowed all year round since the early 1960s. In this subarea fishing is carried out mainly by purse-seiners, which account for over 90% of the total catch (the remaining part of the catch being caught by 'other coastal boats' such as liners, drifters, etc.). As a result, species that are mainly caught by trawling, e.g. soles, rays, gurnards, anglerfishes, common dentex and john dory, are here either not represented or represent only a small part of the catch when compared with the remaining subareas, although all of these species are also normally found in this subarea (Papaconstantinou et al., 1989). In addition, the enclosed nature and the restricted bathymetry (depth < 110 m) of subarea 11 may limit the abundance of larger pelagic species, such as bluefin tuna and swordfish, and of deeper water demersal species, such as blue whiting, respectively. These facts may explain the relatively low diversity of this subarea. In addition, the pelagic catches of subarea 11 fluctuated greatly from 78 t in 1984 to 1081 t in 1985, and this was almost totally due to the annual fluctuations in the catches of anchovy (from 27 t in 1984 to 936 t in 1985). As a result, the relative species composition of the pelagic catch changed accordingly. Overall, the remainder of the subareas were open to all methods of fishing and were fished for all of those species which were of value and present in them.

While it is not the purpose of this paper to provide detailed management plans for the demersal and pelagic fisheries of the Aegean Sea areas in question, it appears clear that the main geographical areas identified will need to be considered as separate entities when management plans are prepared. Although it is obvious that separate management consideration needs to be given to the demersal and pelagic fisheries, the combinations of subareas of the Aegean Sea which need to be considered as 'management units' are different in the cases of these two main (i.e. pelagic and demersal) fisheries (Figs. 4 and 5). In addition, the Greek demersal fisheries resources overall (Stergiou and Petrakis, 1993) are either fully exploited or overfished. The pelagic resources, however, are considered to be currently underexploited, with the exception of anchovy (Stergiou, 1990; Stergiou et al., 1993). Hence, the need for rational management is primarily urgent for the demersal fisheries.

The inadequacy of the management regulations currently in force for demersal and inshore fisheries in Greek waters (i.e. closed seasons and areas, limited issue of licenses, minimum legal landing sizes and mesh size regulations) has been discussed by Stergiou and Petrakis (1993) and justified by the fact that, despite the enforcement of such measures, these resources are currently overfished. This must be attributed mainly to the multi-species, multi-gear nature of the Greek fisheries (and of the Mediterranean fisheries in general) which poses certain difficulties in designing and implementing uniform protective measures.

Recent evidence (see reviews by Davis (1989), Bohnsack (1990) and Roberts and Polunin (1991)) indicates that one of the most potentially effective management techniques to enchance the spawning success of inshore demersal and reef fishes, and particularly those contributing to multi-species fisheries, is the creation of marine harvest refugia. Such protected areas, in which fishing is prohibited, allow a certain proportion of the stock to grow to a relatively large size at which overall fecundity is greatly increased. These areas provide not only an abundance of recruits to the surrounding fished areas, but also a certain proportion of the larger adult fishes which may stray out of the refuge areas into those that are fished (Pollard, 1993).

Such a measure as the creation of marine harvest refugia may be potentially applicable in the case of the Aegean Sea demersal and inshore coastal fisheries because of their extreme multi-species, multi-gear nature (Table 1), and the great difficulty experienced in effectively managing them by any other means. Apart from the more immediate benefits in the enchancement of surrounding fished areas, the longer term benefits of such marine harvest refugia should be to decrease the trend for heavy evolutionary fishing selection for earlier maturity and reproduction and smaller adult fish size (Bohnsack, 1990). The management measures would not only provide protection for population age structure and genetic variability within the stocks, but also of the species composition of the fish community. Marine harvest refugia thus provide a refuge in space rather than a refuge in numbers, the latter being the aim of most traditional fisheries management measures.

Finally, it is worthy of mention that possible measures for the protection of demersal fisheries resources must be spatially adapted for the following reason. It has been suggested (Stergiou, 1992, 1993) that the contrasting spatial differences in nutrient levels in Aegean waters, mentioned above, may be more critical as compared with those in other more generally eutrophic marine regions (e.g. the North Sea), and may have important implications for the fisheries ecology and management of this area. In general, there is evidence suggesting the existence of nutrient-dependent intraspecific geographical differences in life-history parameters (e.g. maximum observed length and age, the Von Bertalanffy growth parameters K and L_∞, natural mortality, length and age at 50% maturation) of, at least, the less mobile demersal species inhabiting Greek waters differing in 'trophic potential' (Stergiou, 1992, 1993). Theoretically, species which mature earlier may be fished at younger ages and at higher levels of fishing mortality and should recover from overfishing more quickly than species which mature later (Adams, 1980; Stergiou, 1992).

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