Belg. J. Zool., 135 (2) : 191-197 July 2005

Effect of fishing on community structure of demersal fish assemblages

Mary Labropoulou and Costas Papaconstantinou

National Center for Marine Research, Agios Kosmas, 166 04 Hellinikon, Greece
Corresponding author : Mary Labropoulou, e-mail : mlabro@ncmr.gr

ABSTRACT. Seasonal experimental trawl surveys (fall 1991-winter 1993) carried out in the Thracian Sea and Thermaikos Gulf (N. E. Mediterranean, Greece). In this area, fishing pressure is very high, since approximately 50% of the Greek otter trawl fleet operates here, producing more than 57% of the total demersal landings. From a total of 285 bottom trawls sampled at depths between 16-420 m, 157 fish species were caught. Indices of diversity, richness, evenness, dominance and ABC plots were used to assess spatial structure, seasonal changes and diversity of the demersal fish assemblages. In general, species diversity, richness and evenness decreased with water depth, with the highest values at depths <100 m. Dominance increased with depth, getting its maximum at depths >200 m. The effect of depth on the diversity patterns observed was always significant, while no seasonal trends were detected. Commercially important species were dominant in the shallowest zone, while non-commercial species predominated at depths below 200 m. At intermediate depths (30-200 m) almost 50% of the total catches comprised of non-commercially important fish species. The abundance/biomass comparison method proved a useful tool for assessing the impact of stresses on fish populations since it revealed moderate disturbance on fish communities at those depths where fishing pressure is the highest.

KEY WORDS : Community structure, diversity, ABC method, fishing effects, North Eastern Mediterranean

INTRODUCTION

The reductions of catch rates and mean size of individuals is well documented in world fisheries (PITCHER, 1996, PAULY *et al.* 1998). Consequently, new approaches to the study of exploited populations have been suggested, including the study of the fish assemblage structure in relation to environmental variables, and the characterization of seasonal changes to improve management practices (i.e. GISLASON *et al.* 2000). As pointed out by CADDY & SHARP (1988) this type of study is a necessary step towards understanding the dynamics of multispecies stocks. Such work can then be extended to find general patterns, which may be associated with particular environmental conditions and fishing effort.

Information on soft-bottom fish assemblages is particularly scarce in the Eastern Mediterranean region where demersal fish are heavily exploited as principal targets or as by-catch. In Greek waters, demersal fishes of the continental shelf and slope are subjected to an intensive fishery carried out by trawl, gillnet and longline fleets. Gillnets and longlines catch a small number of species, whereas the trawl fleet exploits a multi-species fishery targeting several demersal and benthic species. The results of experimental trawl fishing in the Greek seas indicate that commercially important demersal and inshore stocks suffer from growth over-fishing. As a result, commercial catches consist mainly of young immature individuals and a variety of non-commercial species that are discarded (STERGIOU *et al.*, 1997).

In the present study, trawl catch data obtained seasonally, between fall 1991 and winter 1993, from the continental shelf and the upper slope of the Thracian sea were analysed to investigate the structure of the demersal fish community. The main objective was to identify aspects of community structure that are most likely to reveal evidence of anthropogenic impact due to exploitation.

MATERIALS AND METHODS

Sampling procedure

A total of 285 hauls were taken during 8 experimental bottom trawl survey cruises on a seasonal basis (fall 1991-winter 1993) in the Thracian Sea and Thermaikos Gulf from standard depth stations between 16-420 m. Sampling stations were selected on a depth-stratified random decision and the otter trawl used (foot-rope length : 65.7 m, headline height : 1.5 m) was equipped with a cod-end bag liner of 16 mm stretched mesh size. Samples were collected during daylight between 08:00 and 17:00 hours. The duration of each trawl (bottom time) was 30-60 min and the trawling speed fluctuated from 2.5 to 3.0 knots depending on the depth and the nature of the substrate. The catch from each haul was sorted and identified to species level, and each species was enumerated and weighed separately on board. Since all hauls were carried out using the commercial trawl vessel ('Ioannis Rossos') and the same fishing gear, it was assumed that gear selectivity was constant. Those species regarded as pelagic or semi-pelagic in behaviour were excluded from the analyses since they had not been quantitatively sampled (i.e. *Scomber* sp., *Trachurus* sp., *Sardina pilchardus*, *Engraulis encrasicolus*).

Data analysis

Species abundance and biomass were calculated for each haul after standardization of the data to a 1 hour tow. Cluster analysis (group average) employing the Bray-Curtis similarity index (Field *et al*., 1982) was performed to the standardized abundance values of the species using the PRIMER algorithms, Plymouth Marine Laboratory (Clarke, 1993). In order to normalize the data and avoid skew a square root transformation was applied to the abundance data prior to cluster analysis (Field *et al*., 1982). Multidimensional scaling (MDS) ordination analysis was also performed with the same configuration as in cluster analysis with respect to similarity index and transformation. The typifying and discriminating species of each group of stations were determined using the SIMPER procedure (Clarke, 1993). This procedure indicates the average contribution of each species to the similarity (typifying species) and dissimilarity (discriminating species) between groups of samples. Variation in species relative abundance and biomass was also examined by using the graphical representations of species cumulative frequency distributions (*k*-dominance curves, Lambshead *et al*., 1983). Relative abundance and biomass of demersal species were superimposed using the *ABC* method of Warwick (1986) to provide information on the size of the most dominant species. The ecological parameters number of species (*S*), species diversity (Shannon-Wiener index, Hurlbert, 1978), richness (Margalef, 1968), dominance (Simpson's index, Krebs, 1989) and evenness (Pielou, 1966) were calculated for each of the station-groups defined by cluster analysis.

RESULTS

A total of 157 species belonging to 60 families were collected from 285 trawl stations at depths ranging from 16 to 420 m. On the basis of classification and ordination of the 285 hauls, in terms of species abundance, 4 major station-groups (I to IV) were distinguished, reflecting depth-related differences in demersal fish assemblages associated with the continental shelf and the upper slope (Fig. 1). Group I included stations from intermediate depth (30-90 m), while group II comprised all the deepest stations from the continental shelf (100-190 m). Group III consisted entirely of the shallow stations (16-28 m). All stations from the upper slope (200-420 m) were classified in group IV. Species dominated in each group are presented in Table 1. However, a relatively small number of species contributed most to the similarity of each group, but their relative abundances varied between adjacent groups (i.e. Groups I-III) (Table 1).

Table 1. Dominant fish species in the Thracian Sea and Thermaikos Gulf, based on abundance rank for each station group identified by cluster analysis. Densities (%N) are averaged over all samples in each group. % Cum: average contribution to the similarity in each group. C indicates commercially important species. SD : Standard Deviation

Group III (16-28 m) average similarity: 67.8 SD: 4.9	% N	% Cum.		Group I (30-90 m) average similarity: 73.8 SD: 7.1	% N	% Cum.	
Arnoglossus laterna	13.55	12.37	C	*Serranus hepatus*	17.36	7.85	
Serranus hepatus	8.75	23.29		*Trisopterus minutus capelanus*	17.59	15.12	C
Diplodus annularis	4.24	32.27		*Mullus barbatus*	7.44	21.29	C
Gobius niger	6.74	40.72		*Arnoglossus laterna*	10.12	27.00	C
Mullus barbatus	30.75	48.11	C	*Merluccius merluccius*	3.21	32.08	C
Trisopterus minutus capelanus	1.21	53.63	C	*Spicara flexuosa*	6.92	37.10	
Spicara flexuosa	5.43	59.14		*Lepidotrigla cavillone*	2.75	41.71	
Trigla lucerna	1.61	64.48	C	*Cepola rubescens*	2.34	46.23	
Merlangius merlangus euxinus	3.54	69.45	C	*Deltentosteus quadrimaculatus*	5.35	50.73	
Scorpaena notata	0.45	74.15	C	*Callionymus maculatus*	3.40	55.06	
Merluccius merluccius	0.76	78.50	C	*Scyliorhinus canicula*	2.45	58.74	
Gobius paganellus	4.45	82.18		*Citharus linguatula*	1.67	62.33	C
Solea vulgaris	4.45	85.36	C	*Lophius budegassa*	0.90	65.76	C
Cepola rubescens	0.65	88.03		*Serranus cabrilla*	0.84	68.74	
				Symphurus ligulatus	0.58	71.51	
				Gaidropsarus sp.	0.42	74.05	
				Raja clavata	0.15	76.18	C
				Arnoglossus thori	0.75	78.27	C
Group II (100-190 m) average similarity: 73.6 SD=4.4	**% N**	**% Cum.**		**Group IV (200-420 m) average similarity: 72.3 SD: 7.8**	**% N**	**% Cum.**	
Trisopterus minutus capelanus	27.74	10.17	C	*Hymenocephalus italicus*	14.71	11.03	
Merluccius merluccius	10.16	18.29	C	*Gadiculus argenteus argenteus*	24.52	21.95	
Argentina sphyraena	2.04	23.95		*Lepidorhombus boscii*	5.30	31.81	C
Lophius budegassa	2.26	29.31	C	*Micromesistius poutassou*	26.42	40.85	C
Lepidorhombus boscii	1.38	34.50	C	*Coelorhynchus coelorhynchus*	2.41	47.97	
Arnoglossus laterna	2.46	39.37	C	*Phycis blennoides*	1.06	54.59	C
Scyliorhinus canicula	2.18	44.11		*Lophius budegassa*	1.14	61.12	C
Lepidotrigla cavillone	4.05	48.77		*Argentina sphyraena*	14.07	67.63	
Callionymus maculatus	2.54	53.41		*Merluccius merluccius*	6.88	74.03	C
Cepola rubescens	1.59	57.88		*Galeus melastomus*	0.50	78.95	
Serranus hepatus	6.99	62.10		*Trigla lyra*	0.37	82.62	C
Capros aper	0.88	66.07		*Capros aper*	0.16	86.12	
Phycis blennoides	0.31	69.75	C				
Aspitrigla cuculus	1.68	73.02	C				
Trigla lyra	0.33	76.27	C				
Mullus barbatus	4.53	79.52	C				

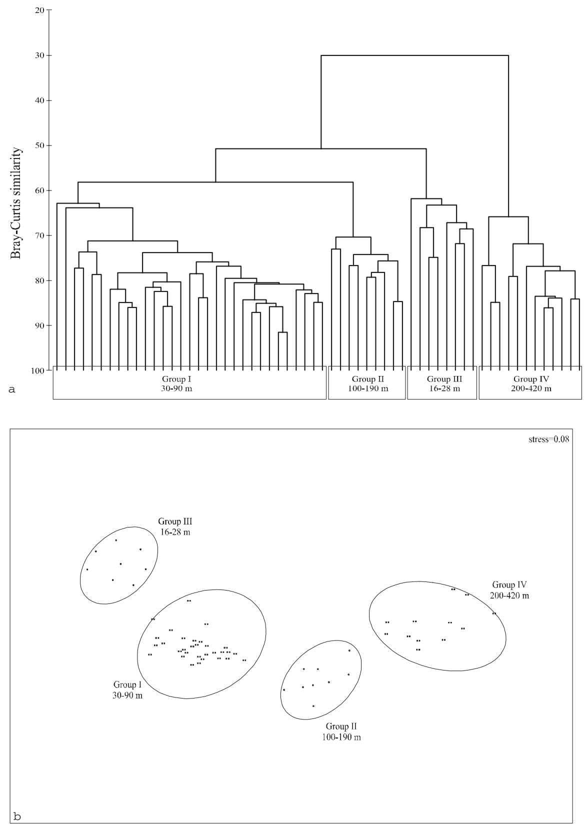

Fig. 1. – Classification (a) and ordination (b) of the sampling stations based on species abundance from the Thracian Sea and Thermaikos Gulf.

Differentiation between groups of station was evident in the *k*-dominance curves, in terms of both number and weight. Stations corresponded to groups I and II revealed more diversified and less dominated communities than those from the upper slope (group IV), with shallow stations (group III) having an intermediate position (Fig. 2). The curves got steeper and more elevated for group IV, suggesting that depths below 200 m were dominated by fewer species. Combined *k*-dominance curves for number and biomass (Fig. 3) showed that the dominant species occupied a larger proportion of the total when expressed as biomass rather than as numerical abundance in groups III and IV. At high species rank, both curves were steeper in gradient, indicating that fish assemblages in groups III and IV were dominated by few species. On the contrary, the *k*-dominance plots for group I exhibited an inverted pattern with the abundance curve more elevated than the biomass curve, indicating that several of the numerically most abundant species are small in size. A combination of large and small species, each with different rank in terms of abundance and biomass, produced *k*-dominance curves, which crossed for those hauls taken from depths between 100-190 m depth (group II). Estimations of the mean commercial/noncommercial ratio in terms of both number and weight of the species consisting each group revealed that commercially important species were dominant in the shallow zone (16-28 m). At intermediate depths (30-200 m) almost 50% of the total catches comprised of non-commercially important species, while non-commercially species predominated at depths below 200 m (Table 2).

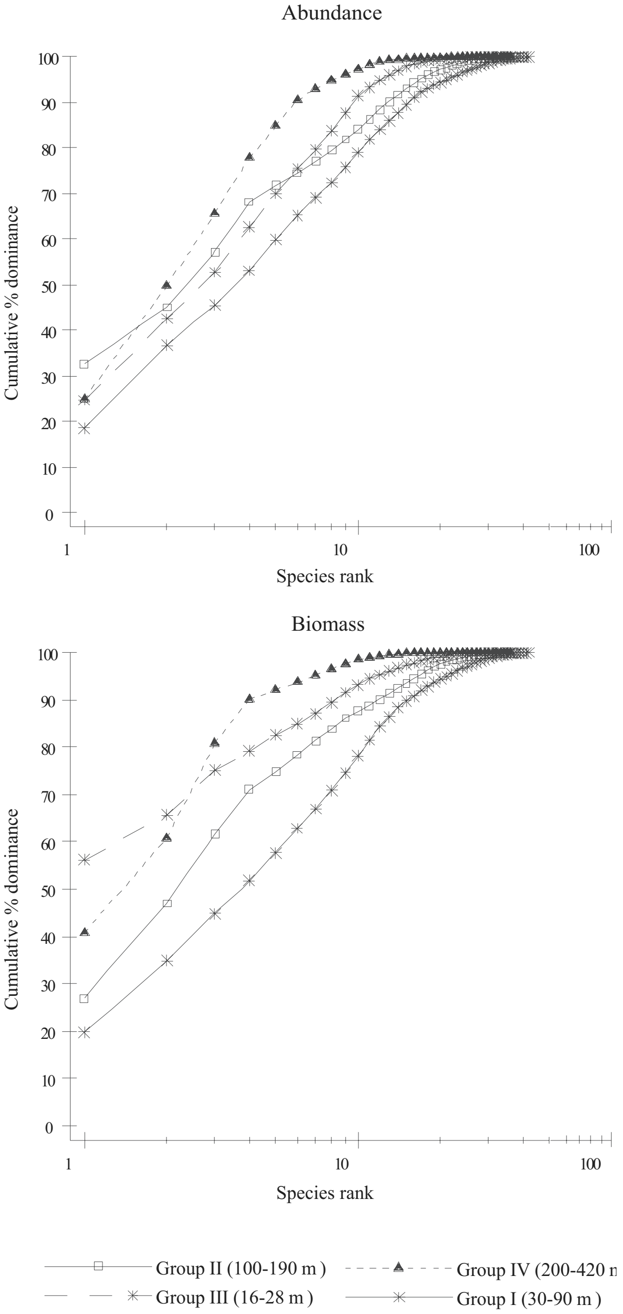

Fig. 2. – Cumulative species richness curves in the four group identified by cluster analysis

Table 2. Estimates of commercial / non commercial ratio by number and weight for species in each group identified by cluster analysis

Commercial / non-commercial ratio	**Group III (16-28 m)**	**Group I (30-90 m)**	**Group II (100-190 m)**	**Group IV (200-420 m)**
Number	1.30	0.79	1.03	0.70
Weight	1.53	0.96	1.10	0.74

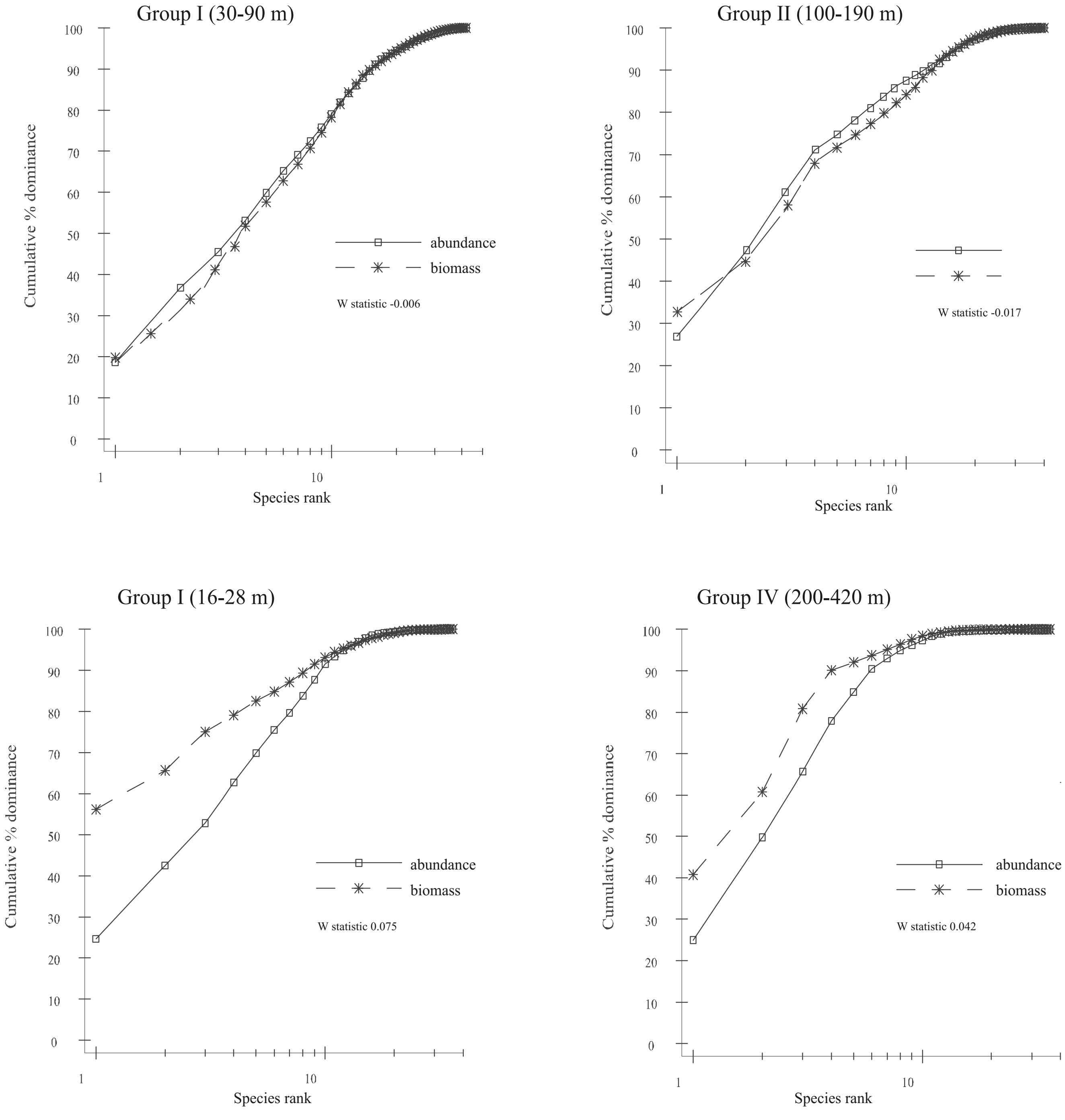

Fig. 3. – Comparison of *k*-dominance curves (abundance and biomass) for the demersal fish communities between the four station-groups from the Thracian Sea and Thermaikos Gulf

Significant differences in mean species abundance, biomass and diversity indices existed between the four station-groups (Fig. 4). The highest values of these parameters were found in samples from the continental shelf (Groups II and III, 30-190 m depth). A converse trend was noted from 200 m down to the maximum depth sampled (Group IV), as well as for the shallowest stations (<30 m, group I). However, ecological parameters appeared to be more or less uniform at depths between 30-190 m (P>0.05, Tukey HSD test). A steady decrease was observed for the stations of the upper slope together with the shallow-water coastal stations.

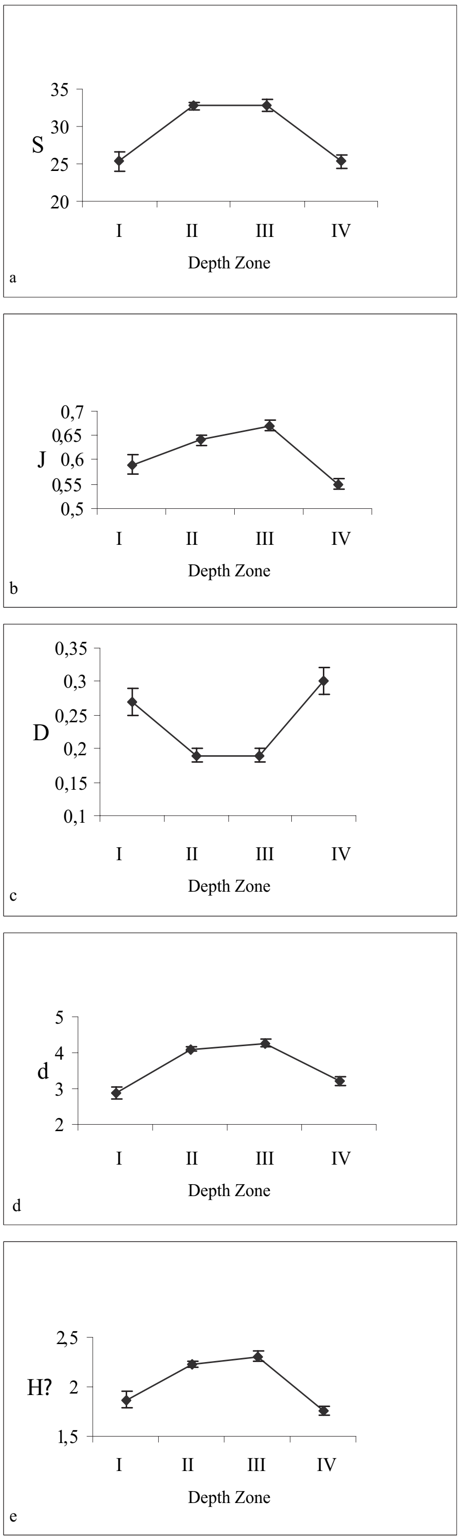

Fig. 4. – Ecological parameters (a : number of species, b : evenness, c : dominance, d : richness, e : Shannon-Wiener diversity) by depth zone (I : 16-28 m, II : 30-90 m, III : 100-190 m, IV : 200-420 m) for the demersal fish communities in the Thracian Sea and Thermaikos Gulf

DISCUSSION

Four distinct demersal fish assemblages were clearly associated with the topography of the study area. A shallow assemblage reached to about 30 m and represents coastal shallow bottom fauna of the continental shelf. Two assemblages corresponded to the middle (30-90 m) and deeper (100-190 m) parts of the continental shelf, and a deep assemblage extended beyond that depth which represents the upper slope. The continental shelf assemblages exhibited greater abundance and contained species of commercial interest such as : *Merluccius merluccius*, *Mullus barbatus*, *Mullus surmuletus, Pagellus erythrinus,* and *Trisopterus minutus capelanus*. The upper slope assemblage is characterized by the predominance of species like *Micromesistius poutassou*, *Gadiculus argenteus argenteus*, *Argentina sphyraena* and *Hymenocephalus italicus*, which are small and not commercially important. The main determining feature associated with the structure of the demersal fish assemblages is depth, as it reflects the changes from the continental shelf to the continental slope. However, other bottom and oceanographic characteristics must also play a role, at least for structuring assemblages on the continental shelf. These include the gradient in eutrophy, fresh/brackish water runoff, temperature and salinity differences along a NNW to SSE axis, and differences in the extent and the bottom type of the continental shelf (STERGIOU *et al.*, 1997). Nevertheless, the most important quantitative boundary for all areas was located around 200 m, a depth separating the species of the continental shelf from those of the upper slope extending down to 500 m.

High species richness and diversity characterized the continental shelf, but both variables decreased markedly at the deepest waters, while the reverse was true for species dominance. On the other hand, evenness also decreased with depth, but remained rather constant at depths between 30-190 m, indicating little variability in the numerical codominance of species over the continental shelf. The disparities in these general trends for the shallowest depths (group III) may be attributed to the more variable environmental characteristics (temperature and salinity) in shallow coastal waters. The *k*-dominance analysis suggested that the spatial trend in diversity and dominance was a strong feature of the species assemblages under study, with dominance being the highest in group IV. Consequently it appears that the highest values of species diversity at depths between 30-190 m, coincided with those depths where fishing pressure has been the greatest.

Increasing levels of disturbance have generally been considered to decrease diversity, species richness and evenness. These observations have also been made in many studies as response of demersal fish communities to intense fishing effort (GREENSTREET & HALL, 1996 ; RIJNSDORP *et al.*, 1996 ; HALL, 1999 ; JENNINGS *et al.*, 1999). However, recent theories on the influence of disturbance or stress on diversity suggest that at intermediate levels of disturbance, diversity could be the highest (MURAWSKI, 2000). Fishing might cause major species replacement but the actual changes in their reletive abundance are rather subtle. Other changes in assemblage's species composition generally involve relatively rare species and thus indices based on multispecies information do not always reflect major species replacement events (MURAWSKI, 2000). Therefore, depending on the starting point of the community in relation to existing stress levels, increasing levels of stress may either result in an increase or decrease in diversity. BIANCHI *et al.* (2000), who investigated whether changes in diversity and dominance of demersal fish communities could be related to fishing, concluded that the largest changes in diversity appeare to be due to changes in evenness or species richness, or both, often leading to an increase in diversity in response to heavy exploitation. Since diversity measures have a specific sensitivity to changes in weight or numbers, dominant or rare species occurrrences, evenness among species and other attributes (MAURAWSKI, 2000), no consensus has developed yet on the utility of traditional diversity indices as a measure of ecosystem overfishing (JENNINGS & REYNOLS, 2000 ; RICE, 2000).

Some spatial effects of fishing in the study area were adequately well illustrated by abundance/biomass comparison (*ABC*) method. The logic behind using *ABC* curves to evaluate effects of perturbations is that in undisturbed communities the presence of large organisms results in the biomass curve lying entirely above the abundance curve, due to the dominance of few large species each represented by few individuals (WARWICK & CLARKE, 1994). Under environmental stress the communities become increasingly dominated by large numbers of small individuals and the abundance curve lies entirely above the biomass curve. In moderate disturbed communities these curves closely coincident and may cross over one or more times (WARWICK, 1986). This method has successfully been used for assessing the degree to which macrobenthic communities respond to increasing levels of pollution-induced disturbance (WARWICK, 1986 ; WARWICK *et al.*, 1987 ; WARWICK & RUSWAHYUNI, 1987 ; MEIRE & DEREU, 1990 ; WARWICK & CLARKE, 1994). Recently, PENCZAK & KRUK (1999) who employed the *ABC* comparison method for detecting human impacts on freshwater fish populations reported that it proves a useful tool for indicating disturbance in fish communities. Although *ABC* curves have not been widely used for evaluating fishery impacts on fish community structure, it appears, in the present study, that they can be a useful tool as an indicator of overfishing. The biomass and abundance curves are close together, crossing each other at depths between 30 and 190 m, where fishing pressure is the highest. Together with the negative values of *W* statistics obtained, these results indicate moderate disturbance of demersal fish communities. Also present in these communities are small, non-commercially important fish species, as confirmed by SIMPER analysis. These species are numerically dominant but do not represent a large proportion of the community biomass.

Studies in other areas, based on extended time series during which major increases in fishing effort took place, indicate that fishing leads to a decrease in catches and to increases in non-commercial species (OVERHOLTZ & TYLER, 1985 ; ROTHSCHILD, 1992). Furthermore, there is evidence that the size structure of demersal fish communities is affected by fishing (PAULY *et al.*, 1998). The overall trend is one of a reduction in large fish and a relative increase in small fish (BIANCHI *et al.*, 2000 ; ZWANENBURG, 2000). In the present study, the fish assemblages under consideration have suffered a long history of fishery exploitation. Therefore overfishing has affected the population structure and densities of the demersal fish communities, at least at depths up to 200 m, where most of the fishing activity is focused. It is possible that the organization of the demersal fish assemblages analysed is determined to a great extent by unidirectional trend induced by fishing, bottom topography and oceanographic features of the study area.

REFERENCES

BIANCHI, G., H. GISLASON, K. GRAHAM, L. HILL, X. JIN, K. KORANTENG, S. MANICKCHAND-HEILEMAN, I. PAYÁ, K. SAINSBURY, F. SANCHEZ & K. ZWANENBURG (2000). Impact of fishing on size composition and diversity of demersal fish communities. *ICES J. Mar. Sci.*, 57 : 558-571.

CADDY, J.F. & G.D. SHARP (1988). An ecological framework for marine fishery investigations. *FAO Fish. Tech. Pap.* 283.

CLARKE, K.L. (1993). Non-parametric multivariate analyses of change in community structure. *Aust. J. Ecol.*, 18 : 117-143.

FIELD, J.G, K.R. CLARKE & R.M. WARWICK (1982). A practical strategy for analysis of multispecies distribution patterns. *Mar. Ecol. Prog. Ser.*, 8 : 37-52.

GISLASON H., M. SINCLAIR, K. SAINSBURY, R. O' BOYLE (2000). Symposium overview : incorporating ecosystem objectives within fisheries management. *ICES J Mar Sci 57* : 468-475.

GREENSTREET, S.P.R. & S.J. HALL (1996). Fishing and the ground-fish assemblage structure in the Nort-western North Sea : an analysis of long-term and spatial trends. *J. Anim. Ecol.*, 65 : 577-598.

HALL, S. (1999). *The effects of fishing on marine ecosystems and communities*. Blackwell Science, London.

HURLBERT, S.H. (1978). The measurement of niche overlap and some relatives. *Ecology* 59 : 67-77.

JENNINGS S., S.P.R. GREENSTREET & J.D. REYNOLDS (1999). Structural changes in an exploited fish community : a consequence of differential fishing effects on species with contrasting life histories. *J. Anim. Ecol.*, 68 : 617-627.

JENNINGS, S. & J.D. REYNOLDS (2000). Impacts of fishing on diversity : from pattern to process. In : KAISER M.J. & S.J. de GROOT (eds), *Effects of fishing on non-target species and habitats, Biological, conservation and socio-economic issues*, Blackwell Scientific, Oxford : 235 -250.

KREBS, C.J. (1989). *Ecological methodology.* Harper and Row, New York.

LAMBSHEAD, P.J.D., H.M. PLATT & K.M. SHAW (1983). The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. *J. Nat. Hist.*, 17 : 859-874.

MARGALEF, R. (1968). *Perspectives in ecological theory.* University of Chicago Press, Chicago, Illinois.

MEIRE, P.M. & J. DEREU (1990). Use of the abundance/biomass comparison method for detecting environmental stress : some considerations based on intertidal macrozoobenthos and bird communities. *J. Appl. Ecol.*, 27 : 210-223.

MURAWSKI, S.A. (2000). Definitions of overfishing from an ecosystem perspective. *ICES J. Mar. Sci.*, 57 : 649-658.

OVERHOLTZ, W.J. & A.V. TYLER (1985). Long-term changes of the demersal fish assemblages of Georges Bank. *Fish. Bull.*, 83 : 507-520.

PAULY D., V. CHRISTENSEN, J. DALSGAARD, R. FROESE & F.C. Jr TORRES (1998). Fishing down marine food webs. *Science,* 279 : 850-863.

PENCZAK, T. & A. KRUK (1999). Applicability of the abundance/ biomass comparison method for detecting human impacts on fish populations in the Pilica River, Poland. *Fish. Res.*, 39 : 229-240.

PIELOU, E.C. (1966). The measurement of diversity in differences types of biological collections. *J. Theor. Biol.*, 13 : 131-144.

PITCHER, A. (1996). Reinventing fisheries management. *NAGA ICLARM*, 19(3) : 15-17.

RICE, J.C. (2000). Evaluating fishery impacts using metrics of community structure. *ICES J Mar. Sci.*, 57 : 682 -688.

RIJNSDORP, K.J., P.I. van LEEUWEN, N. DAAN & H.J.L. HEESEN (1996). Changes in abundance of demersal fish species in the North Sea between 1906-1909 and 1990-1995. *ICES J. Mar. Sci.*, 53 : 1054-1062.

ROTHSCHILD, B.J. (1992). Multispecies interactions on George Bank. *ICES Mar. Sci. Symp.*, 195 : 418-423.

STERGIOU, K.I., E.D. CHRISTOU, D. GEORGOPOULOS, A. ZENETOS & C. SOUVERMEZOGLOU (1997). The Hellenic Seas : physics, chemistry, biology and fisheries. *Oceanogr. Mar. Biol. Ann. Rev.*, 35 : 415-538.

WARWICK, R.M. & RUSWAHYUNI (1987). Comparative study of the structure of some tropical and temperate marine soft-bottom macrobenthic communities. *Mar. Biol.* 95 : 641-649.

WARWICK, R.M. (1986). A new method for detecting pollution effects on marine benthic communities. *Mar. Biol.*, 92 : 557-562.

WARWICK, R.M. & K.R. CLARKE (1994). Relearning the ABC : taxonomic changes and abundance/biomass relationships in disturbed benthic communities. *Mar. Biol.*, 118 : 739-744.

WARWICK, R.M., T.H. PEARSON & RUSWAHYUNI (1987). Detection of pollution effects on marine macrobenthos : further evaluation of the species abundance/biomass method. *Mar. Biol.*, 95 : 193-200.

ZWANENBURG, K.C.T. (2000). The effects of fishing on demersal fish communities of the Scotian Shelf. *ICES J. Mar. Sci.*, 57 : 503-509.