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# Assessment of demersal distribution between two fishing areas in North and Central Greece

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**Abstract**

The site specific CPUE and biomass of the demersal fauna were assessed in two sampling areas situated in Pieria (north Greece, lower Thermaikos) and Argolikos bay (central Greece). In total 22 hauls were conducted 12 of which in Pieria and 10 in Argolikos between January and August of 2009. The demersal fauna showed differences between number of taxa, number of individuals, abundance and biomass between the sampling sites. *Mullus barbatus*, *Trachurus mediterraneus* and *Diplodus annularıs* were the most dominant species in the area of Pieria (40% of the total abundance), whilst the most dominant species in Argolikos were *Mullus barbatus*, *Lepidopus caudatus* and *Diplodus annularıs* (60% of the total abundance). Species richness, diversity, evenness and numerical abundance were higher in Pieria. Cluster analysis and multidimensional scaling indicated differences between the two sites. Abundance biomass curves suggested that both sites are moderately disturbed, whereas K-dominance curves suggested that Pieria was slightly more impacted but not statistically significant compared to Argolikos.

**Keywords:** CPUE, Biomass, Demersal, Pieria, Argolikos

## Introduction

A central challenge in fisheries ecology is to understand why species abundance changes over time (Sissenwine 1984; Cushing 1990). Species can experience different environmental conditions and survival rates throughout their distribution range (Kareiva 1990; Tilman et al. 1997; Ciannelli et al. 2007) and these conditions usually influence the observed abundances. Moreover it is well established that species-environment interactions are complex, as they vary over different observational scales (Fauchald et al. 2000) and can be non linear (Stenseth et al. 2002; Dingson et al. 2007) and nonadditive (Ciabbelli et al. 2004a).

The Greek trawl fishery has a total annual catch of about 20,000 tones, representing some of 15% of the total marine catch, 26% of its wholesale value (Stergiou et al. 1997a). An important feature of fishing in Greek waters is that trawling is banned from 1 June to 30 September. Target species for trawl fisheries in the Aegean sea are composed primarily of demersal and benthopelagic fish of different body shape and size such as red mullet (*Mullus barbatus*), red pandora (*Pagellus erythrinus*), hake (*Merluccius merluccius*) and annular sea bream (*Diplodus annularis*).

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The spatial distribution of marine organisms is highly patchy over a range of spatial and temporal scales (Murphy et al. 1988; Fauchald et al. 2000; Fauchald and Erikstad 2002). This spatial complexity is a result of the interplay between ecological and behavioral interactions and the physical environment of the sea (Wiens 1989; Ricklefs 1990; Mann and Lazier 1991; Levin 2000). Moreover, the various abiotic and biotic processes operate on different spatial and temporal scales (Levin 1992).

Recent ecological studies have focused on the causes of community structuring (Wiens 1986; Roughgarden 1989; Sale et al. 1994). Analyses of the spatial heterogeneity of species assemblages have often been made in this connection, since these provide an overall view of processes affecting community structure (Schoener 1974; Hanski 1990; Tilman 1994). In marine ecology, since the middle of the 1980s, the role of intrinsic factors (i.e. specific interactions among assemblage members) on the structuring of species assemblages has been shown to be less important than was previously thought (Sale et al. 1994). For instance, Mahon and Smith (1989) noted that the spatial pattern of ground-fish distribution on the Scotian shelf is strongly influenced by the physical environment much more so than by specific interactions.

Among other extrinsic factors, habitat characteristics can strongly influence the spatial organization of ground-fishes (Mahon 1985; Hutchings 1990; Perry and Smith 1994; McCormick 1995). When studying shelf and upper-slope demersal assemblages, depth is often reported to be the main gradient along which faunal changes occur (Fager 1968; Mahon and Smith 1989; Bianchi 1992; Gordon and Bergstad 1992; Weinberg 1994; Gaertner et al. 1998). Other components of the habitat such as the benthos (Jones et al. 1991; McCormick 1995) and type of substratum (Mahon 1985; Bianchi 1992; Perry et al. 1994; McCormick 1995) are also known to influence the structure of species assemblages. The identification of associations between species and their habitat can lead to a better understanding of environmental influences on fish distribution and migration patterns (Rose and Legett 1988; Xie and Hsieh 1989).

Our goal was to compare the demersal fish assemblages between two fishing areas and identify possible differences among them.

## Materials and methods

The gulf of Thermaikos (Fig. 1) lies to the east of Pieria prefecture located in the southern part of Macedonia, in the Periphery of Central Macedonia immediately south of Thessaloniki opening into the Aegean Sea. The length is about 100 km and the width is 5 km near Thessaloniki, about 15 km to the north and as far as about 50 km to the south. The rivers emptying into the gulf are Pineios, Aliákmon, Loudias, Gallikos, and Axios. The gulf of Thermaikos is closed, relatively shallow gulf characterized by flat bottom with low gradient (Karageorgis et al. 2005). The Gulf of Argolikos (Fig. 1) is a small gulf off the east coast of the Peloponnese, Greece, opening into the Aegean Sea, surrounded by two prefectures, Arcadia and Argolis. Argolikos gulf is an open gulf with 54 km in length and maximum width 20 km. On the western part bottom gradient is very high with a narrow continental shelf, at the eastern part the bottom gradient is high and the continental shelf is wider and at its northern part the gulf has a low gradient with a much wider continental shelf.

In total 22 hauls were conducted, 12 of which in Thermaikos and 10 in Argolikos gulfs between January and August of 2009. Hauls for each sampling area were conducted on the same geographical coordinates in each area in order to acquire reliable and comparable results. The typical duration of a trip was one day, the duration of each haul varied between 30 min and 1 hour and fishing depth ranged between 31 and 65 meters. For each haul the position, minimum and maximum depths, duration of the haul, as well as the stratum at which the trawl operated at least for the 50% of the haul were recorded. The bottom type was mud in all hauls. The bottom trawl used in both areas had a vertical opening of <1.8 m and horizontal opening of 12 m. Sampling was carried out using commercial trawl nets with a stretched mesh size of 28 mm (knot to knot) and trawling speed was 2.5 knots/hour for each haul. Water temperature and salinity at each sampling area were recorded using a CTD (SBE SEACAT Profiler) throughout the water column at 1 m intervals. For comparison abundance was expressed as numbers per hour trawling and biomass as grams per hour trawling.

Field work included estimating the total catch per haul, as well as recording the faunistic composition of the catch, listed as fish, cephalopods and crustaceans for which the identification was made to the species level. After the marketable catch was sorted by the crew, the number of boxes was counted and their weight calculated. The discarded portion of the catch was also put in boxes, the number of which was counted and weighted. Discarded

species were sorted out, the number of the individuals recorded and their length and total weight per species noted. In cases where certain species numbered many specimens, a representative sample was examined.

Fig. 1. The Gulf of Thermaikos in the north (top arrow) and the gulf of Argolikos in the south (bottom arrow)

The community structure was studied using diversity indices, which attempt to combine data on abundance within a species in a community into a single number (univariate analysis) and by assessing similarities among communities (multivariate analysis) using Cluster analysis allowing to identify either the degree of similarity in species composition between sampling sites thus permitting recognition of clusters of species or communities (Ismael and Dorgham 2003).

K-dominance curves, which rank species in decreasing order of their abundance on the x-axis (logarithmic scale) with the percentage of the total abundance of all species in the sample on the y-axis (cumulative scale), were used to detect possible pollution-induced disturbance in the marine communities. These curves are widely used for the detection of pollution effects on macro-benthos (Warwick 1986; Warwick et al. 1987; Clarke 1990)

Cluster analysis was based on Bray-Curtis similarity index (Bray and Curtis 1957) with the PRIMER package (Clarke and Warwick 1994). To normalize the data and to avoid skewness, a fourth root transformation was applied on the abundance data prior to calculating similarities (Field et al. 1982). Diversity was calculated by means of the (log2) Shannon-Wiener index (Shannon and Weaver 1949), species richness (R) was calculated after Margalef (1958) and species evenness (E) after Pielou (1977).

K-dominance curves, with cumulative ranked abundance plotted against species rank, in decreasing order of their importance were used as a graphical representation of the impacts relating to levels of biological stress (Clarke and Warwick 1994).

Data for statistical analysis were evaluated for normal distribution by employing the Anderson-Darling test for normality, and homogeneity of variance by assessing residual plots and employing Bartlett's and Levene's tests when necessary data transformation was performed. A non-parametric Kruskal-Wallis test was used for analysis (Dytham 2003) since assumptions of the ANOVA test were not met. The results did not differ from those based on ANOVA.

## Results

In total 90 species were recorded 63 of which in Pieria (Thermaikos gulf) and 70 in the gulf of Argolikos. The average abundance (numbers/hour trawling) for all 12 hauls conducted in Pieria was 5,398 individuals per hour trawling whereas in all 10 hauls conducted in Argolikos gulf average abundance was 4,038 individuals per hour trawling. The average biomass (grams/hour trawling) in Pieria was 134,563 and 143,064 in Argolikos. *Mullus*

*barbatus*, *Trachurus mediterraneus* and *Diplodus annularıs* were the most dominant species in the area of Pieria (40% of the total abundance) (Table 3), whilst the most dominant species in Argolikos were *Mullus barbatus*, *Lepidopus caudatus* and *Diplodus annularıs* (60% of the total abundance) (Table 4).

The similarity percentage programme SIMPER (Clarke 1993) was used to investigate the contributions of individual species caught to the observed dissimilarities between Pieria and Argolikos (Tables 1 and 2). *Trachurus mediterraneus* was the principal contributor (Table 1) to the dissimilarities between samples of Pieria and Argolikos and their average abundance followed by *Diplodus annularıs*, *Lepidotrigla cavillone* and *Mullus barbatus*.

Table 1. Top 10 ranked species responsible for the observed dissimilarities between samples of Pieria and Argolikos and their average abundance (numbers/h trawling) and individual contribution (%) to the average dissimilarity value

| Species | Average Abundance (Numbers/h trawling) | | % | % Average dissimilarity |
|---|---|---|---|---|
| | Pieria | Argolikos | | |
| *Trachurus mediterraneus* | 783 | 45 | 11.7 | 63.90 |
| *Diplodus annularıs* | 532 | 746 | 10.6 | |
| *Lepidotrigla cavillone* | 26 | 611 | 9.9 | |
| *Mullus barbatus* | 900 | 793 | 8.6 | |
| *Pagellus bogaraveo* | 210 | 259 | 6.6 | |
| *Serranus hepatus* | 475 | 151 | 6.1 | |
| *Pagellus erythrinus* | 407 | 544 | 5.7 | |
| *Arnoglossus laterna* | 321 | 0 | 5.4 | |
| *Spicara flexuosa* | 358 | 124 | 5.1 | |
| *Pagellus acarne* | 123 | 271 | 4.9 | |

Table 2. Top 10 ranked species responsible for the observed dissimilarities between samples of Pieria and Argolikos and their average biomass (grams/h trawling) and individual contribution (%) to the average dissimilarity value

| Species | Average Biomass (grams/h trawling) | | % | % Average dissimilarity |
|---|---|---|---|---|
| | Pieria | Argolikos | | |
| *Pagellus erythrinus* | 17183 | 40576 | 14.0 | 61.90 |
| *Diplodus annularıs* | 18927 | 764 | 10.2 | |
| *Mullus barbatus* | 13752 | 22131 | 9.4 | |
| *Trachurus mediterraneus* | 19834 | 24027 | 9.1 | |
| *Pagellus acarne* | 4169 | 15321 | 8.4 | |
| *Lepidotrigla cavillone* | 425 | 10423 | 6.2 | |
| *Merluccius merluccius* | 8650 | 6693 | 5.6 | |
| *Spicara flexuosa* | 9221 | 3264 | 4.5 | |
| *Pagellus bogaraveo* | 5920 | 1880 | 4.2 | |
| *Serranus hepatus* | 6678 | 1220 | 3.4 | |

*Pagellus erythrinus* was the principal contributor (Table 2) to the dissimilarities between samples of Pieria and Argolikos and their average biomass followed by *Diplodus annularıs*, *Mullus barbatus* and *Trachurus mediterraneus*. The number of taxa, abundance, species richness (d) (Margalef), diversity (H') (Shannon-Weiner), evenness (J) (Simpson), and equitability were all higher in Pieria (Thermaikos gulf) compared to Argolikos gulf. The non-parametric test Kruskal-Wallis indicated no significant difference in number of taxa, abundance and

species richness between the two sampling sites. However the non-parametric test Kruskal-Wallis indicated significant differences in diversity (H'), evenness (J) (Simpson), and equitability (Fig. 2).

Table 3. Abundance (%) of major taxa at Pieria study sites comprising more than 85% of the total abundance over all sampling cruises per group and station (+:<1%, O: Osteichthyes, C: Cephalopods)

| Species/ Study Site | Phyllum | S_01 | M_01 | D_01 | S_03 | M_03 | D_03 | S_04 | M_04 | D_04 | S_06 | M_06 | D_06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Arnoglossus laterna* | O | 9,17 | 2,44 | 2,05 | 7,24 | 9,21 | 5,81 | 3,50 | 13,35 | 4,23 | 5,26 | 6,13 | 5,45 |
| *Cepola rubescens* | O | + | | + | 2,28 | 4,18 | 1,97 | + | 2,63 | 1,06 | + | 1,99 | 1,71 |
| *Citharus linguatula* | O | 9,22 | 2,44 | 4,67 | + | + | + | 2,20 | 4,02 | 2,00 | 6,98 | 2,68 | 3,49 |
| *Diplodus annularıs* | O | 5,73 | 4,47 | 2,62 | 1,66 | 5,39 | 2,07 | 6,08 | 16,81 | 7,73 | 22,42 | 25,46 | 22,0 |
| *Engraulis encrasicolus* | O | | | + | 1,45 | + | 2,07 | + | + | + | 4,70 | 4,91 | 5,57 |
| *Illex coindetii* | C | + | + | | | | | 18,3 | + | 1,36 | | + | + |
| *Lepidotrigla cavillone* | O | 1,53 | + | 2,54 | + | 1,19 | | | + | + | + | | + |
| *Merluccius merluccius* | O | 2,70 | 3,72 | 3,11 | + | + | + | + | + | + | 3,52 | 2,12 | 2,26 |
| *Mullus barbatus* | O | 23,3 | 24,02 | 29,86 | 16,4 | 12,5 | 11,20 | 26,9 | 19,41 | 17,76 | 8,59 | 10,70 | 8,45 |
| *Pagellus acarne* | O | | + | 0,00 | 11,2 | 3,75 | 1,74 | + | 2,18 | 4,57 | + | | + |
| *Pagellus bogaraveo* | O | 3,21 | 6,91 | 15,09 | + | | + | + | 1,02 | 27,69 | + | | + |
| *Pagellus erythrinus* | O | 2,92 | 15,93 | 5,44 | 7,26 | 5,11 | 3,79 | 7,64 | 7,60 | 3,85 | 9,30 | 13,94 | 9,85 |
| *Sardina pilchardus* | O | + | + | + | | | + | | | | 1,51 | + | 3,66 |
| *Serranus hepatus* | O | | 14,00 | 7,50 | 9,03 | 19,9 | 10,29 | 7,87 | 15,42 | 8,92 | 5,71 | 4,91 | 6,05 |
| *Serranus serranus* | O | 13,9 | | | | | | | | | | | |
| *Spicara flexuosa* | O | 15,1 | 14,09 | 15,78 | 5,89 | 3,48 | 7,21 | 4,46 | 3,84 | 4,50 | 2,65 | 1,22 | 3,90 |
| *Spicara smaris* | O | | | | | | | | | | | | + |
| *Squilla mantis* | O | | | | + | + | + | + | 4,25 | 3,85 | 1,34 | 1,19 | 1,31 |
| *Trachurus mediterraneus* | O | 2,28 | 5,69 | 1,80 | 26,4 | 26,4 | 46,43 | 16,0 | 1,32 | 8,33 | 6,42 | 6,08 | 5,01 |
| *Trisopterus minutus capelanus* | O | 2,22 | | 3,15 | 3,86 | + | + | + | + | + | 12,42 | 11,75 | 12,2 |
| Cumulative abundance (%) | | 92,7 | 94,99 | 95,01 | 94,9 | 93,5 | 94,09 | 97,0 | 94,61 | 97,31 | 91,93 | 93,69 | 91,2 |

The mean Shannon-Weiner diversity index for Pieria was 2.38 whereas for Argolikos was 1.91 indicating greater biodiversity in Pieria compared to Argolikos (Fig. 2). The mean Simpson index for Pieria was 0.86 whereas for Argolikos was 0.79 indicating greater evenness in the benthic communities of Pieria compared to Argolikos. Margalef's richness index was higher in the area of Pieria (3.33) in comparison to the area of Argolikos (3.04) indicating higher species richness in the area of Pieria. Equitability index was higher in the area of Pieria (0.71) compared to the area of Argolikos (0.59), indicating that the evenness with which individuals are divided among the taxa was greater in Pieria (Fig. 2).

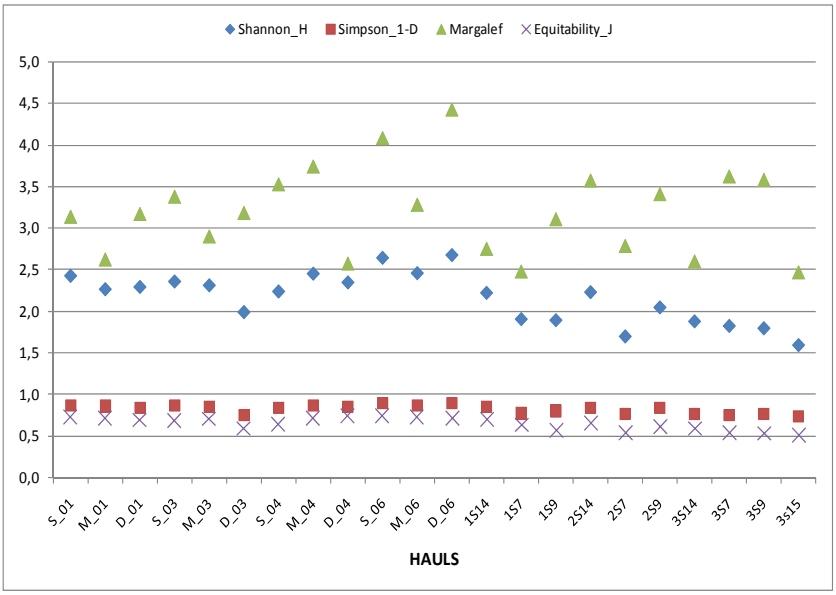


Fig. 2. Diversity indices for each haul in both sampling sites

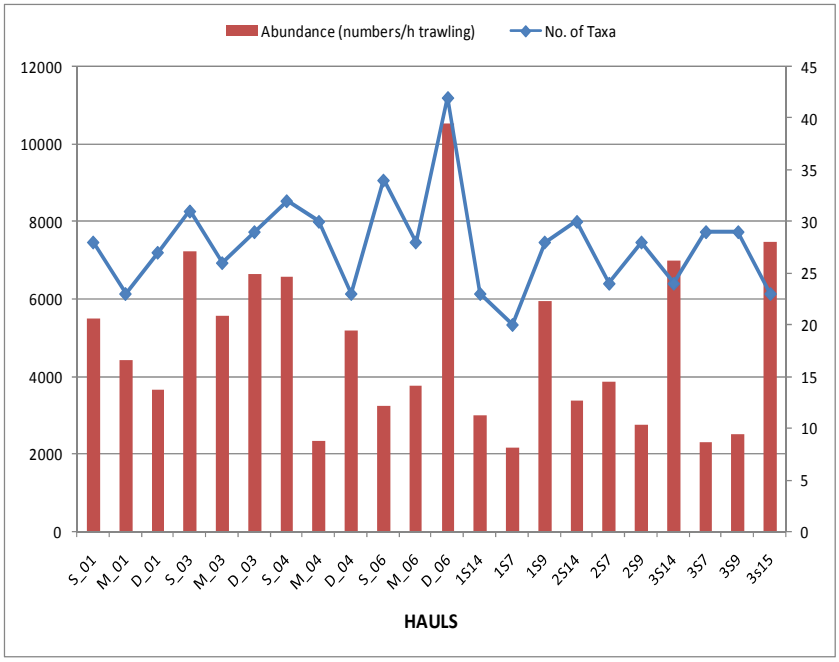


Fig. 3. Number of species and individuals recorded at each haul in both sampling sites

The mean number of individuals was greater in Pieria (5,388) compared to Argolikos (4,033). In addition the mean number of taxa in Pieria (29.4) was greater in comparison to Argolikos (25.8) (Fig. 3). As a graphical representation of impacts K-dominance curves were used with cumulative ranked abundance plotted against species rank, in decreasing order of their importance (Fig. 4). Species rank was log transformed for a smoothing effect on curves and to better visualize the distribution of commoner species. More elevated curves have lower diversity, supposedly representing more impacted sites (Lambshead et al. 1983).

Table 4. Abundance (%) of major taxa at Argolikos study sites comprising more than 85% of the total abundance over all sampling cruises per group and station (+:<1%, O: Osteichthyes, C: Cephalopods).

| Species/ Study Site | Phyllum | 1S14 | 1S7 | 1S9 | 2S14 | 2S7 | 2S9 | 3S14 | 3S7 | 3S9 | 3s15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cepola rubescens* | O | | | | | | | | + | | + |
| *Citharus linguatula* | O | 1,44 | 3,71 | + | 1,19 | 1,55 | 2,97 | 1,43 | 5,15 | 1,60 | + |
| *Diplodus annularıs* | O | | | 26,16 | 10,55 | 5,72 | 14,71 | 17,16 | 18,34 | 31,44 | 33,61 |
| *Engraulis encrasicolus* | O | | | | | | | | + | | + |
| *Illex coindetii* | C | | 1,39 | | + | + | + | | | | |
| *Lepidotrigla cavillone* | O | | | 11,35 | | | | | | | |
| *Lepidopus caudatus* | O | 27,17 | 18,35 | | 16,51 | 9,40 | 26,65 | 39,89 | 14,69 | 4,49 | |
| *Merluccius merluccius* | O | 7,61 | + | 1,97 | 1,43 | + | + | + | | | |
| *Mullus barbatus* | O | 10,07 | 17,13 | 25,77 | 5,02 | 19,74 | 19,98 | 18,10 | 41,61 | 29,99 | 16,95 |
| *Pagellus acarne* | O | | 1,70 | 3,00 | 1,01 | 35,12 | 10,86 | 8,49 | 1,12 | + | 2,38 |
| *Pagellus bogaraveo* | O | | | | | | | | + | 1,60 | 34,01 |
| *Pagellus erythrinus* | O | 12,00 | 39,16 | 20,91 | 7,77 | 24,17 | 10,93 | 4,03 | 10,07 | 20,29 | 6,28 |
| *Sardina pilchardus* | O | | | | | | | | + | | |
| *Serranus hepatus* | O | 8,94 | 5,41 | + | 12,15 | + | 7,62 | 2,29 | 1,04 | 3,13 | 2,57 |
| *Spicara flexuosa* | O | 14,96 | + | 5,38 | 6,94 | 2,12 | 2,03 | + | 2,46 | + | |
| *Spicara smaris* | O | + | 1,39 | + | 29,34 | + | | | + | | |
| *Squilla mantis* | O | | + | | | + | | | | | + |
| *Trachurus mediterraneus* | O | 6,93 | 5,26 | 1,89 | + | | + | | | | + |
| Cumulative abundance (%) | | 89,92 | 94,90 | 98,15 | 92,32 | 98,97 | 96,02 | 91,82 | 95,23 | 93,10 | 96,28 |

K-dominance curve of Argolikos shows higher elevation compared to the K-dominance curve of Pieria indicating that Argolikos is more impacted in terms of biological stress (Fig. 4). The Abundance Biomass Comparison (ABC) method was initially proposed by Warwick (1986) as a technique for monitoring disturbance (mainly pollution effects) on benthic invertebrate communities by comparing dominance in terms of abundance with dominance in terms of biomass (Fig. 5 and 6). The ABC method takes into account the number of species included in the analysis (Warwick and Clarke 1994). Subsequently, it has been applied to marine benthic communities in different regions, and in most cases showed the expected changes in response to disturbance (Warwick et al. 1987; Agard et al. 1993). The difference between the two curves is given by the Wstatistic, which represents the area between them.

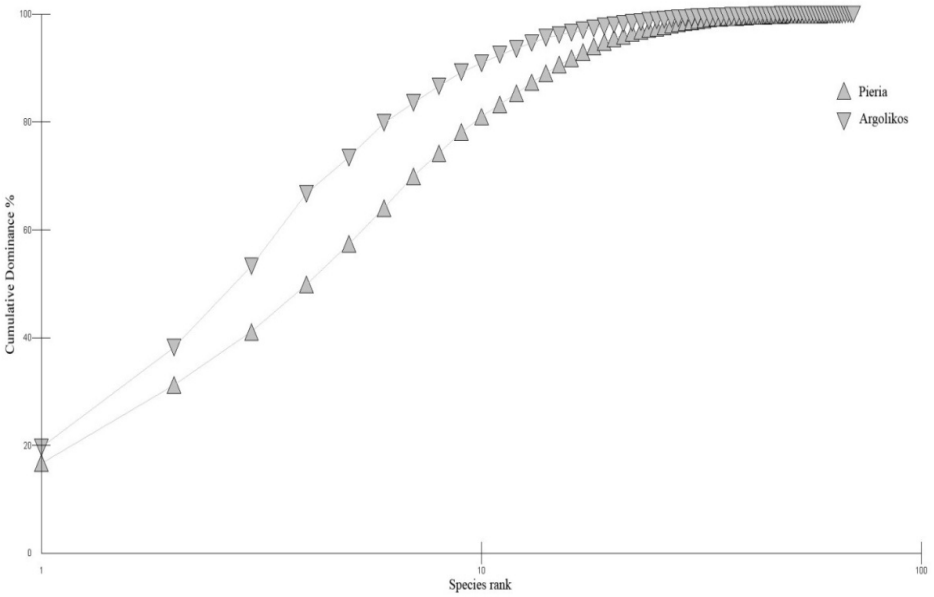


Fig. 4. K-dominance curves for Pieria and Argolikos sites

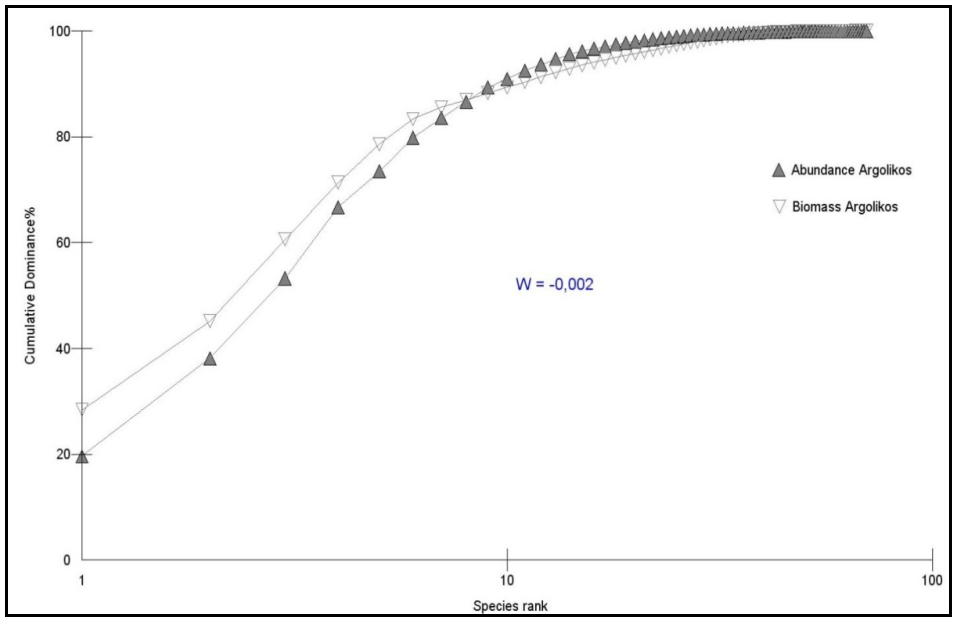


Fig. 5. ABC curves of Argolikos assemblages

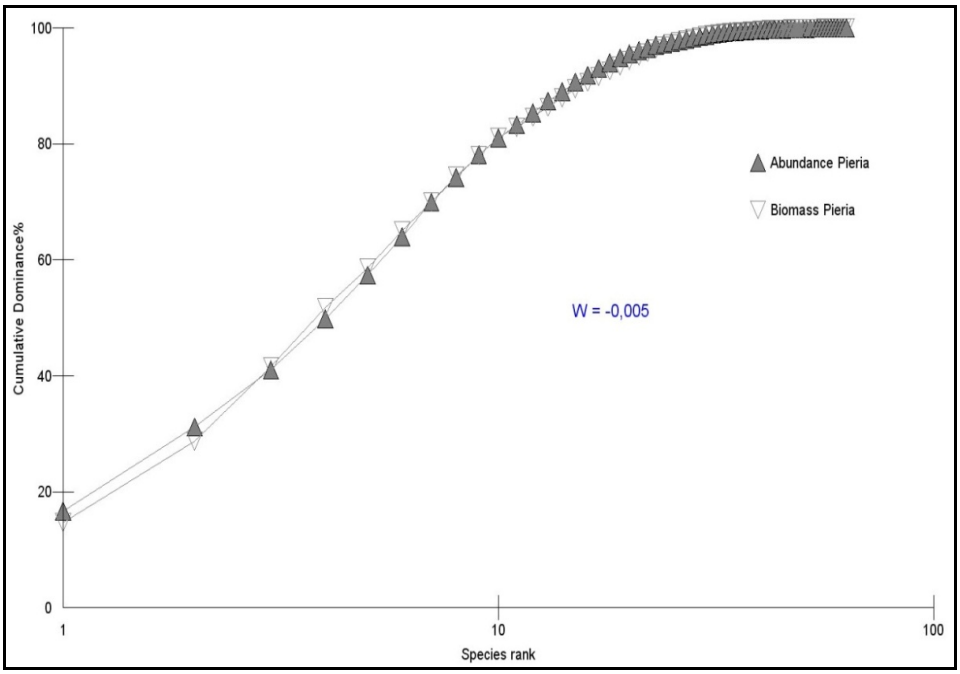


Fig. 6. ABC curves of Pieria (Thermaikos gulf) assemblages

The negative sign of Wstatistic for both Argolikos and Pieria demersal assemblages indicates that the biomass curve lies below the abundance curve and suggests a disturbed community for both sampling sites (Figs. 5 and 6). However there is the indication that Argolikos gulf is a more disturbed site since the biomass curve is slightly below the abundance curve.

Multidimensional scaling (MDS) provided a spatial representation of the abundance facilitating interpretation and revealing relationships between and within sampling sites (Fig. 7). The MDS indicated the presence of two distinct groups the Argolikos and Pieria groups. There is also the indication that the Pieria group is more uniform and displays higher degree of similarity between hauls compared to Argolikos group.

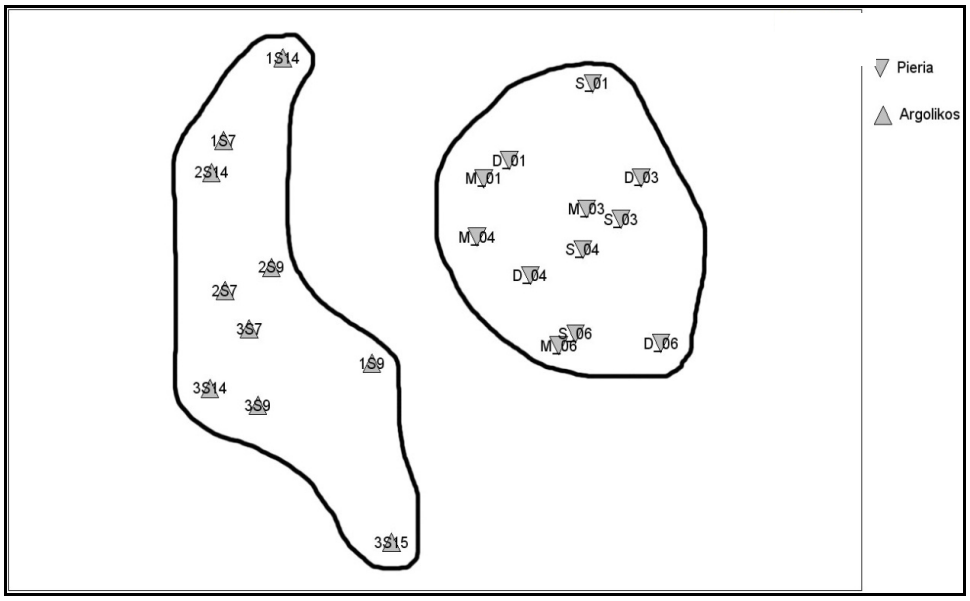


Fig. 7. Multidimensional scaling of the faunal abundances at the study sites

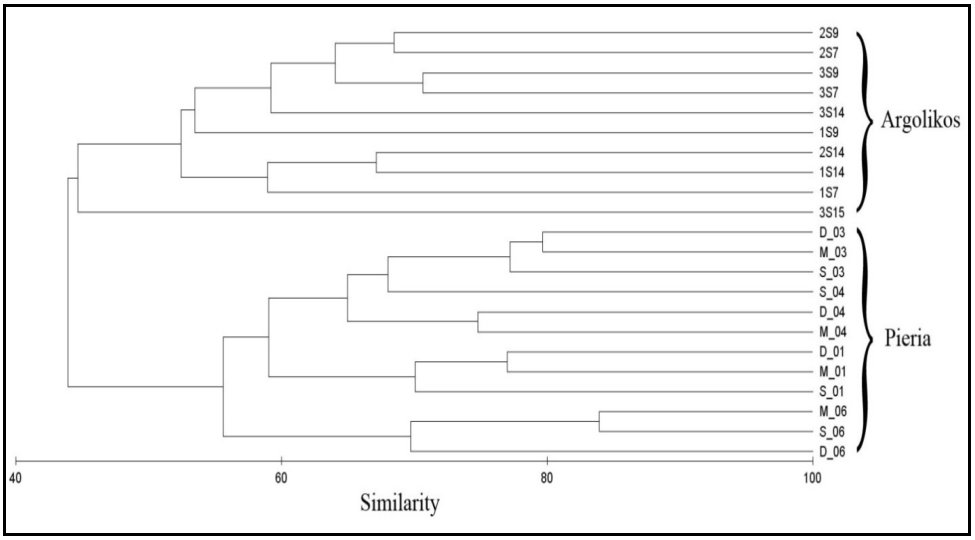


Fig. 8. Dendrogram for hierarchical clustering of the faunal abundances at the study sites, using group-average clustering of Bray-Curtis similarities based on 4$^{th}$ root-transformed abundances

Cluster analysis (Fig. 8) based on Bray-Curtis similarity index indicated the presence of two major Groups Argolikos gulf and Pieria (Thermaikos gulf) with 43% similarity. The group of Argolikos is at the 45% similarity level whereas the group of Pieria is at 57% similarity level.

## Discussion

The results indicated a difference between the two fishing areas regarding both abundance and biomass. Numerical abundance was higher in Pieria (Thermaikos gulf) whereas biomass was higher in Argolikos gulf. The most dominant species in the area of Pieria were *Mullus barbatus*, *Trachurus mediterraneus* and *Diplodus annularıs*

(40% of the total abundance) (Table 3), similarly the most dominant species in Argolikos were *Mullus barbatus*, *Lepidopus caudatus* and *Diplodus annularıs* (60% of the total abundance) (Table 4).

SIMPER analysis indicated that the species mainly responsible for the dissimilarity in abundance between sampling sites were *Trachurus mediterraneus, Diplodus annularıs, Lepidotrigla cavillone* and *Mullus barbatus* (Table 1). Similarly the species mainly responsible for the dissimilarity in biomass between sampling sites were *Pagellus erythrinus*, *Diplodus annularıs, Mullus barbatus* and *Trachurus mediterraneus* (Table 2).

The number of taxa, abundance, species richness (*d*), diversity (*H'*), evenness (*J*), and equitability were higher in Pieria (Thermaikos gulf) compared to Argolikos gulf. No significant differences were observed in the number of taxa, abundance and species richness between the two sampling sites. However significant differences were observed in diversity (*H'*), evenness (*J*), and equitability between sampling sites.

The K-dominance curves displayed a non-significant elevated curve for both Argolikos and Pieria demersal assemblages suggesting a slightly more disturbed site in Argolikos gulf area. Multidimensional scaling indicated the presence of two distinct assemblages in Argolikos and Pieria with the indication that the assemblage in Pieria group is more uniform compared to Argolikos assemblage. Cluster analysis indicated the presence of two major groups one in Argolikos gulf and another one in Pieria (Thermaikos gulf) with 43% similarity. The group of Argolikos had a 45% similarity level whereas the Pieria group had 57% similarity.

Results indicate that the area of Pieria (Thermaikos gulf) is a less impacted area with higher degree of uniformity, displaying greater diversity compared to the area of Argolikos gulf. Possible reasons could be greater fishing effort in the area of Argolikos and unfavorable geomorphology compared to the area of Pieria. Furthermore in the gulf of Thermaikos there is possibly a considerably higher fresh water input deriving by a number of large rivers and smaller streams, especially during the winter months.

This river input coupled with transfer of large quantities of organic material could lead to increase primary and secondary productions ultimately resulting in an area with higher productivity in comparison to the gulf of Argolikos. Fishing has significant direct and indirect effects on the habitat, diversity, and productivity of communities. The main effect of trawling is increased mortality of marketable as well as discarded species (Stergiou et al. 1998; Hall, 1999). Because of its significant impact on primary production, a river plume may have an indirect effect on ground-fish assemblages through other components of the ecosystem such as sediment type and primary production. In temperate systems, the temporal succession of stratification (density-gradient induced between marine and freshwaters) and vertical mixing (wind-induced) enhances primary production (Cushing 1989) and, through the food web, increases ground-fish production (Mann 1993).

The preferred environment of a species is determined by many biotic and abiotic parameters, such as prey abundance or predator avoidance, temperature, salinity, bottom type etc. (Rose and Leggett 1989; Smith et al. 1991; Swain 1993). The geographical distribution of a species can depend on the density of the population and so may change between years (MacCall 1990; Swain and Wade 1993); in some cases it is considered to be age or size dependent (MacPherson and Duarte 1991; Sinclair 1992; Swain 1993).

For many demersal fish, a positive correlation between size of fish and depth has been reported (Macpherson and Duarte 1991; Sinclair 1992; Swain 1993). Furthermore, the density of fish may vary within the surveyed area since gradients can occur related to oceanographic parameters like water depth, salinity, temperature etc. (Daan et al. 1990; Gunderson 1993).

For successful fisheries management, a knowledge of the environmental conditions that control the structure of exploited ground-fish assemblages can (a) improve abundance estimates of bottom-trawl surveys (Smith 1990; Smith et al. 1991); (b) help identify species assemblages for multi-species fisheries management (Mahon and Smith 1989) and (c) expand our understanding of the role of the environment in variations of catchability (Perry and Smith 1994).

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