NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N4536 **NAFO SCR Doc. 01/142**

SCIENTIFIC COUNCIL MEETING – SEPTEMBER 2001
(Deep-sea Fisheries Symposium – Oral)

Size Influence in Zonation Patterns in Fishes and Crustaceans from Deep-water Communities of the Western Mediterranean

by

B. Morales-Nin[1], F.Maynou[2], F.Sardà[2], J.Cartes[2], J.Moranta[1], E.Massutí[3], J.Company[2], G.Rotllant[2], A.Bozzano[2], C. Stefanescu[4], and Can Liró[4]

[1] CSIC/UIB-IMEDEA, Esporles, Spain
[2] CSIC-ICM, Barcelona, Spain
[3] IEO-COB, Palma de Mallorca, Spain
[4] E-08458 Sant Pere de Vilamajor, Spain.

Abstract

The depth distribution of different taxa (fishes and decapod crustaceans) composing deep-sea communities in the SW Balearic Islands collected at two seasons, were analysed to compare the intensity of faunal change with depth to individual size, measured as mean individual weight, both within and between fish and decapods. The results are discussed on the light of the biological characteristics of the populations studied. Our conclusion is that there are complex distributions on mean weight by depth, determined mainly by trophic aspects and biological adaptations to the oligotrophic deep Mediterranean conditions.

Introduction

During the last decades, zonation in deep-sea megafaunal communities has been increasingly studied (Vinogradova, 1962; Haedrich *et al*., 1975; 1980; Smith and Hamilton, 1983; Hecker, 1990; among others). Although fish was the main target taxa studied (Haedrich and Kreft, 1978; Gordon and Duncan, 1985; Haedrich and Merret, 1990; Koslow, 1993, Fujita *et al*., 1995; Stefanescu *et al*., 1992a; 1993; Moranta *et al*., 1998) probably due to their dominance in communities from mid-latitudes, zonation has also been documented in other megabenthic taxa, like crustaceans and other benthos (Rowe and Menzis, 1969; Abelló *et al*., 1988; Fredj and Laubier, 1985; Cartes, 1993; Cartes and Sardà, 1993; Maynou and Cartes, 2000). Comparative zonation studies between different groups are, however, scarce (Gage and Tyler, 1991), although the taxon factor, together with bottom topography, has been one of the most widely argued reasons to explain discrepancies in zonation (the intensity of faunal change with depth) at a regional scale (Gage and Tyler, 1991). Differences in intensity of zonation (rate of faunal change) amongst deep-sea fauna has been explained as a function of individual size (Gage and Tyler, 1991), with megafauna changing most rapidly and infaunal polychaetes the slowest. These differences amongst megafauna seem closely related to dispersal capability of species in their early development (Tyler and Gage, 1994).

The deep-bathyal Mediterranean communities showed the co-dominance of two megabenthic taxa (fish and crustacean decapods), which allows to attempt the study of size influence in depth zonation in two diversified taxa. In the deep N-W Mediterranean Sea, there is a boundary between 350 and 550 m, separating upper and middle slope decapod crustacean communities (Abelló *et al*., 1988; Cartes *et al*., 1994). The boundary between the middle and lower slope was established at around 1200 m (Cartes and Sardà, 1992; Cartes, 1993). The zonation of fish communities is characterized by the presence of two boundaries, located at 800 and 1400 m depth between upper-middle and middle-lower slope, respectively (Stefanescu *et al*., 1993; Moranta *et al*., 1998). Trophic reasons, especially the influence of mesopelagic prey in the diet of bathyal species only to 1,200-1,300 m depth, has been indicated as cause of this pattern in the Catalan Sea area (Cartes, 1998, and references cited therein). The different depth patterns shown by each taxon may be attributed to the different fractions of the food resource, or food spectrum, exploited by each taxon (Maynou and Cartes, 2000). Although the existence of boundaries or discrete faunistic groups related to sharp variations in environmental conditions are well known, zonation seems to depend both on local topographic features and of taxa studied, being more a regional than a general phenomenon and it seems problematic to extrapolate to wide geographical areas (Haedrich and Merret, 1990).

Although the depth-size trends have been studied for decapod crustaceans (Sardà and Cartes, 1993) as well as for fishes (Macpherson and Duarte, 1991; Stefanescu *et al*., 1992b), there is not a comprehensive study of community size structure by depth. In the present study we tested faunal zonation for the different dominant taxa (fish and decapod crustaceans) composing deep-sea communities in the S Balearic Islands (Algerian Basin).

Material and Methods

Sampling

The data examined in the present study were collected south of the Balearic Islands (Western Mediterranean), between $38^{0}48'$ N and $38^{0}05'$ N on two cruises, QUIMERA I in autumn (October 1996) and QUIMERA II in spring (May 1998). The two cruises were carried out on board the RV "Garcia del Cid" (38 m length, 1500 HP), and the sampling gear used was an OTMS-27.5 (headline length 25 m) type bottom trawl, trawled on a single warp (Sardà *et al*., 1998).

A total of 46 hauls were taken between depths of 200 and 1800 m (32 in the Q-I and 14 in the Q-II) (Fig. 1a). Haul duration ranged from 30 to 60 min. Towing speed was 2.7 knots for all hauls. The arrival and departure of the net to the bottom in addition to the horizontal and vertical openings (14m and 1.8 to 2m, respectively) were measured using the SCANMAR system (the cod-end mesh size was 12 mm). For each haul, the total amount of the fresh catch was weighed, all the individuals were counted, and the total amount (or a subsample) were weighed and measured. The SCANMAR system allowed to quantify the exact area swept by the trawl, and was used to compute the standardised abundance (number and weight) of the catch $10{,}000 m^{-2}$.The depth distribution of the hauls was stratified in 200 m intervals, with at least two hauls by strata (up to 6 hauls in the 1,400-1,600 m range during Q1) (Fig.1b). A CTD probe was used to determine the environmental characteristics of the water column. The CTD casts were performed along a transect for each oceanographic cruise, using a Seabird 25 probe.

Statistical analysis

The data on megafaunal abundance were plotted over a depth axis to display the trends with depth of the standardized abundance indices and the mean weight by individual was also determined for decapods and fishes.

The bubble scatter plot was applied to the mean weight for the most frequent species to detect the observed abundance tendencies with depth.

The mean weight by species for fish and decapod crustaceans was calculated by haul and included in a species-samples matrix to apply cluster analysis, using the Bray-Curtis similarity index and the UPGMA clustering algorithm. Species recorded only in 10 haul were omitted to avoid noise in the analysis. The mesopelagic fishes (*Argyropelecus hemigymnus, Stomias boa, Lampanyctus crocodrilus, Chauliodon sloani*), although frequent, were not considered for the analysis because they are not well sampled by the net. The identification of the main assemblages was also performed by multidimensional scaling (MDS). The similarity index used in MDS ordination was Pearson´s product moment correlation.

The mean general size (MGS) was calculated for each taxon. The mean weight for each species was plotted on a $\log_2$-scale histogram and the median MGS was calculated for fishes and decapods. After establishing mean general size for each taxon, clustering was applied considering: 1) large fish, those exceeding mean general size (MGS), 2) small fish with mean size below MGS, 3) large decapods exceeding their MGS, 4) small decapods with mean size below MGS. In this way the size factor can be further tested independently of taxa.

Results

Environmental features

The thermal and saline stability reported for the deep Mediterranean sea (Fredj and Laubier, 1985) was confirmed by the CTD casts. Temperature varied between 13.0 and 13.5ºC and salinity between 38.3 and 38.5 psu, from 200 m to the bottom at all localities sampled. The depth profiles showed that the water masses were still structured in the Q1 cruise, with a surface temperature of 21ºC and a strong gradient between 50 and 100 m depth corresponding to summer stratification. During Q2 cruise, the surface temperature was 17.5ºC and thermal stability was reached at around 200 m depth corresponding to early spring oceanographic conditions (Cartes *et al*., 2001).

Species composition and depth profiles

The mean weight and frequency of captured species are summarized for fishes and decapod crustaceans (Tables 1 and 2). A total of 90 fish species and 48 decapod crustaceans were caught being the most frequent the mesopelagic fish *Argyropelecus hemigymnus* followed by *Galeus melastomus* and for decapod crustaceans *Aristeus antennatus*. The mean weight ranged from0.4 to 4,000 g for fishes and from 0.17 to 264.96 g for decapod crustaceans.

Similar tendencies were found in the depth profiles in both cruises for the megafauna (fishes, decapods and cephalopods), fishes and decapod crustaceans, respectively (Fig. 2). The abundance decreased along the slope reaching more or less constant values at 1,000 m with some oscillations. The fishes abundance decreased sharply from the shelf break to 600 m depth, remaining more or less at the same levels and with a secondary peak at about 1,000 m due to the presence of *Alepocephalus rostratus*. Decapod crustaceans dominated in number between 400-800 m and below 1,400 m depth (Fig. 2). The biomass was dominated by fishes due to their larger mean individual weight, and there was a decrease in biomass from the shelf break (200 m depth) with a minimum at 400-600 m depth with a posterior increase at 800 m and a plateau between 800-1,200 m, with a progressive decrease afterwards. The biomass of decapod crustaceans increased from 200 mpeaking between 400-600 m and decreasing afterwards. This peak is inverse to fish biomass that shows a minimum at this depth range. Fishes, although always having a higher mean individual weight, showed much higher individual weights between 800-1,400 m, with a peak at around 1,000 m depth also related to the attendance of the deep-dwelling *A.rostratus* (Fig. 2). The individual mean weight of decapod crustaceans was lower with a trend towards larger sizes at intermediate depths. The trend of the megafauna followed closely the spectrum of fishes. Some variations were found between both cruises in biomass due to the lower values obtained in Q-II between 200-400 m depth.

The non-parametric Spearman correlation coefficient showed not significant relationships between the biomass distribution of fish and crustacean decapods along all the bathymetric range in both cruises (Q-I n=31, r= -0.2851, p=0.09; Q-II n=14, r= -0.4637, p=0.09). Also, there was no correlation between mean weight and depth (r^2=0.0086, F=7.2962>$F_{0.05,722}$).

The size spectra for fishes and decapod crustaceans is presented in Fig. 3. Size classes are according to $\log_2$ (mean weight) and the height of each bar indicates the number of species present in the depth range considered that fall within the particular size class. Decapod crustaceans size spectra is consistently smaller than for fishes, while in both there is a discontinuity in the size distribution.

The blubber plot for the fishes and decapod crustaceans showed different mean individual weight tendencies with depth depending of the species. The fishes which corresponded to the groups dominant in the shallower depths (200-1,000 m) (Fig. 4) showed a trend to larger mean weight with depth, for instance *G.melasomus, H.italicus* and *P.blennoides*, exceptions are *Antonogadus megalokynodon* and *Hoplostethus mediterraneus* with a marked decrease in mean weight, due to the recruitment of small fish in deeper waters. In figure 5 the trends with depth for the fishes predominant at the deeper waters are included. The macrourids showed a clear depth compartimentation, being *Nezumia aequalis* the shallower and *Chalinura mediterranea* the deepest dweller. The typical species of the deep Mediterranean fauna showed an increase in mean weigh with depth (*Lepidion lepidion*, *Alepocephalus rostratus*, *Coelorhynchus labiatus*, *Etmopetrux spinax*).

This complex mean weight pattern depending on the species was also found in decapod crustaceans (Fig. 6 and 7). The crustaceans more abundant in water shallower than 800 m show an increasing mean weight trend (Fig.6).

Large shrimps (*Aristeus antennatus* and *Acanthephyra eximia*) showed a decreasing trend of mean weigh with depth while mesopelagic decapods showed an increasing trend (*Acanthephyra pelagica*, *Gennadas elegans*, *Sergia robusta*, *Pasiphaea multidentata*). Typical deep-sea species (appearing below 1,000 m: *Stereomastis sculpta* and *Nematocarcinus exilis*) (Fig. 7) show an increase in mean weigh, while benthic eurybathic decapods (*Geryon longipes*, *Polycheles typhlops* and *Munida tenuimana*) show complex patterns (U-shaped, parabola). *M.tenuimana* has a contagious distribution, thus the weigh pattern withy great biomass at the two extremes of the depth range, might be due to fortuitous catches in the trawl hauls.

Community characteristics and results of the multifactorial analyses

The species present in more than 10 hauls (Tables 1 and 2) were analysed for size-depth trends. The dendrogram of similarities for the hauls is shown in Figure 8 a. The depth gradient is observable in the four main groups obtained with samples taken between: i) 195-415 m depth, ii) 502-816 m depth, iii) 813-1,416 m depth and iv) 1,407-1,713 m depth. The results of the multidimensional scaling analysis are shown in Fig. 8 b. There are not clearly differentiated groups although it seems that the deeper hauls (<1,000 m depth) are grouped at the right side of the graph.

The dendrogram of similarities for the species is shown in Fig. 9. The first cluster separates fishes and decapod crustaceans from the upper slope with a relative big size, the rest of species are grouped clearly as a medium slope group and a deeper dwelling group. The fishes are grouped in three main groups: i) shallower (*Merluccius merluccius*, *Helicolenus dactylopterus* and *Antonogadus megaloyinodon*), ii) intermediate species (*Notacanthus bonapartei*, *Symphurus ligulatus*, *Hymenocephalus italicus*, *Hoplostetus mediterraneus*, *Phycis blennoides*, *Nezumia aequalis*, *Nettastoma melanurum*, *Mora moro*, *Galeus melastomus*, *Etmopterus spinax*) and iii) deeper water species (*Polyacanthonotus rissoanus*, *Chalinura mediterranea*, *Caelorhinchus labiatus*, *Bathypterois mediterraneus*, *Lepidion lepidion* , *Alepocephalus rostratus*). There is also a further grouping inside each main group, with the species with similar mean size placed more closely than the smaller ones.

When the fish and crustacean decapods below the MGS (small crustaceans: <=2.7 g/ind, small fishes <=50 g/ind.) and over the MGS (large crustaceans >2.7 g/ind., large fishes>50 g/ind) are analysed the deep gradient is also evident. The small fish show four main groupings, corresponding to upper (195-415 and 502-898 m depth), middle (908-1,407 m depth) and lower slope (>1,307 m depth) (Fig.10a). Large fish showed three main groups, due to the fact that the upper boundary is not well established, corresponding to 195-710 m, 802-1,416 m and >1,307 m depth (Fig.10b). Large decapod crustaceans are present only below 300 m depth but showed a similar pattern to big fishes, with a first boundary at 800 m and a secondary one at 1,300 m approximately (Fig. 10d), while the small decapod crustaceans showed an arrangement by depth a first boundary at 600 m and a second one at 1,300 m (Fig.10c).

Discussion

The western Mediterranean slope communities show complex patterns with depth, which differ from the nearby Atlantic Ocean, where fish always dominate and where echinoderms constitute the major invertebrate group (Cartes and Sardà, 1992). In the W Mediterranean decapod crustaceans are the dominant invertebrates, and are abundant and even dominant in number at mid-slope depths (400-800 m) when total megafaunal biomass is low. The relative importance of crustacean decapods in the oligotrophic Mediterranean waters has been hypothesized as a result of their highest competitive trophic strategy (Cartes and Sardà, 1992; Maynou and Cartes, 2000). Although the megafaunal abundance decreases from the shelf break downwards, the biomass, which initially decreases, recovers similar values at 800 m depth. This is due to the higher mean individual weight of fishes between 800-1,400 m depth. There is a clear zonation in species, which result in the described trends. The dominance of species and their relative size show differences depending of the depth range considered. For instance, below 800 m the bigger sizes are found from the species that are characterized by a bigger-deeper trend such as *Phycis blennoides* (Massutí et al., 1996), *Trachyrhynchus trachyrhynchus* (Massutí *et al*., 1995), *Lepidion lepidion* and *Mora moro* (Rotlland *et al*., in press). Moreover, *Alepocephalus rostratus*, a dominant fish in the deep communities which exhibits a clear bathymetric segregation of sizes (Morales-Nin *et al*., 1996), has a high mean individual weight which determines most of the biomass trends at this depth. Decapod crustaceans biomass decreased with depth while their abundance increased below 1,000 m, due to the small size decapod crustaceans (*Gennadas elegans*, *Sergia robusta*, *Acanthephyra eximia*), which are frequent in these deeper waters.

The depth distribution of each sex might also be important in the resulting trends, for instance *Galeus melastomus* and *Etmopterus spinax*, found in the upper slope and the middle slope, respectively, show a similar mean size trend due to the sexual dimorphism with females reaching bigger sizes and being at the depth range of the species distribution (Carrassón *et al*., 1992).

The upper slope (200-800 m), with two zones (200-400 m and 400-800 m), the medium slope (800-1400 m), and lower slope (>1,400 m) zonations were found considering the mean size of fishes and decapod crustaceans. The boundaries between assemblages for megafauna vary among locations (Haedrich *et al*., 1990), however we can compare our results meaningfully with analysis carried out from the same samples (Moranta *et al*., 1998, Maynou and Cartes, 2000). Our results show the same zonations considering the mean weight of the fish and decapod crustaceans, as the ones obtained when the fish abundance was used to determine the demersal fish assemblages (Moranta *et al*., 1998). However, the zonations of the decapod crustacean communities were different, with faunal discontinuities not coincident across taxa (Maynou and Cartes, 2000). This is due to the dominance in weight of fishes, that determine the results of the analysis when the mean weight trends are considered to determine the assemblages.

The factors responsible for the boundaries found in the size distribution within a given habitat, which are commonly accepted are food availability coupled with how species exploit existing food resources and patterns of energy distribution with their overall life strategies (Rowe, 1971; Carey, 1981). However, fish and decapod biomass seem poorly related along all the depth gradient studied. Both taxa did not seem to have a significant trophic dependence between them (Cartes *et al*., 2001). The zonation might be directly or indirectly related to changes in food webs, particularly in the deep Mediterranean where thermal and saline stability occur below 200 m. The major part of deep water megafaunal predators have a high diversified diets and a variety of trophic guilds can be identified within each taxa (Cartes, 1998). It is also well documented that deep-water species prey on different compartments (plankton-benthos) as a function of deep (Cartes, 1998). Trophic aspects have been considered as determinant in the size structure of decapod crustaceans in a neighbouring area (Sardà and Cartes, 1993).

Previous detailed studies performed both on decapod crustaceans and fishes in the Catalan Sea area demonstrated bot at autoecological (see Macpherson, 1979) and assemblages levels (Cartes, 1998) the existence of a resource partitioning in the exploitation of prey by bathial species, though with an increasing dietary overlap with increasing depth among decapods (Cartes, 1998). The fish species with a positive relationship between mean weight and depth are the ones feeding on the water column (*Merluccius merluccius, Galeus melastomus*, *Hymenocephalus italicus*), while the ones that use mainly benthic preys do not show any clear tendency between size and depth, except for *Phycis blennoides* and *Lepidion lepidion*. On the upper slope the dominant fish prey on zooplankton (mainly euphausiids), while in the lower slope zooplankton are the dominant food source for *Alepocephalus rostratus* the dominant species in terms of biomass there (Carrasón, 1994). The deep-sea communities on the study area depend on plankton productivity as the main source of energy (Polunin *et al*., 2001).

The hypothesis that faunal renewal intensity (zonation) depends of individual size of taxa/species considered (Gage and Tyler, 1991) has been tested for the dominant components of the deep-Mediterranean, fish and crustacean decapods. Our results show that this hypothesis seems too simple to explain the zonation in size by depth of the vagile megafauna captured by the trawl. Most fishes and crustaceans are grouped together with a complexity of patterns suggesting that life histories are more important than depth in their size distribution. This complex distribution might be more determined by the trophic aspects and other biological factors, such as physiology (sensory organs, depth adaptations) and biological characteristics, like the dispersion capability of the species, than depth. The oligotrophy of the S Mediterranean might also be determinant in the complex partitioning of resources by the megafauna, which exploit different fractions of the food resource depending of the taxa and consequently show different response patterns to the depth gradient.

Acknowledgements

The Quimera cruises were funded in the framework of the research project `Deep-sea fisheries´(ref.FAIR CT95-0655).

References

-Abelló P.,Valladares, F.J., Castellón, A:(1988) Analysis of the structure of decapod crustacean assemblages ofthe Catalan coast (N-W Mediterranean). Marine Biology, 98, 39-49.

-Carey A.G.(1981) A comparison of benthic infaunal abundance on two abyssal plains in the Northeast Pacific Ocean. Deep-Sea Research ,28, 467-479.

-Carrassón M. (1994) Relaciones tróficas en las comunidades ícticas bentónicas (de 1000 a 2200m) del mar Catalán. PhD Thesis,Universidad Autónoma de Barcelona,Barcelona

-Cartes,J.E. (1993) Deep-Sea decapod fauna of the western Mediterranean: bathymetric distribution and biogeographic aspects.Crustaceana, 65, 29-40.

-Cartes, J.E. (1998) Feeding strategies and partition of food resources in deep-water decapod crustaceans (between 400-2300 m).Journal of the Marine Biological Association of the United Kingdom,78, 509-524.

-Cartes, J.E.& Sardá F. (1992) Abundance and diversity of decapod crustaceans in the deep-Catalan Sea (western Mediterranean).Journal of Natural History, 26, 1305-1323.

-Cartes,J.E. & Sardá,F. (1993) Zonation of deep-sea decapod fauna in the Sea (western Mediterranean).Marine Ecology Progress Series, 94, 27-34.

-Cartes,J.E., Company,J.B. & Maynou, F., (1994) Deep-water decapod crustacean communites in the northwestern Mediterranean: influence of submarine canyons and season. Marine Biology,120, 221-229.

-Cartes, J.E., Maynou, F., Morales-Nin, B., Massutí, E., Moranta, J. (2001) Trophic structure of a bathyal benthopelagic boundary layer community south of the Balearic Islands (southwestern Mediterranean). Marine Ecology Progress Series, 215, 23-35.

-Fredj, G., Laubier L (1985) The deep Mediterranean benthos. In: Moraitou-Apostolopoulou M,Kiortsis V (eds) Mediterranean marine ecosystems.Plenum Press,New York,p 109-146

-Fujita, T., Inada, T., Ishito, Y. (1995) Depth-gradient structure of demersal fish community on the continental shelf and upper slope off Senday Bay, Japan. Marine Ecology Progress Series, 118, 13-23.

-Gage,J.D. & Tyler, P.A., ed., 1991.Deep.Sea biology. Cambridge: Cambridge University Press.

-Gordon JDM, Duncan JAR (1985) The ecology of the deep-sea benthic and benthopelagic fish on the slopes of the Rockall Trough,Northeastern Atlantic. Prog Oceanogr 15: 37-69.

-Haedrich RL, Rowe GT, Polloni PT (1975) Zonation of faunal composition of epibenthic population on the continental slope south of New England. J Mar Res 33:191-212

-Haedrich RL, Krefft G (1978) Distribution of bottom fishes in the Denmark Strait and Irminger Sea. Deep-Sea Res 25:705-720.

-Haedrich RL, Rowe GT,Polloni PT (1980) The megabenthic fauna in the deep-sea south of New England, USA.Mar Biol 57:165-179

-Haedrich RL, Merret NR (1990) Little evidence for faunal zonation or communities in deep sea demersal fish fauna. Prog Oceanogr 24:239-250

-Hecker B (1990) Variation in megafaunal assemblages on the continental margin south of New England. Deep-Sea Res 37:35-57

-Koslow J.A. (1993) Community structure in North Atlantic deep-sea fishes. Prog. Oceanogr. 31, 321-338.

-Macpherson, E. (1979) Ecological overlap between Macrourids in the western Mediterranean Sea. Mar.Biol. 53,149-159.

-Macpherson, E., Duarte, CM. (1991) Bathymetric trends in demersal fish size; is thre a genral relationship? Marine Ecology Progress Series 71, 103-112.

-Massutí, E., Morales-Nin, B., Stefanescu, C. (1995) Distribution and biology of five grenadier fish (Pisces:Macrouridae) from the upper and middle slope of the northwestern Mediterranean. Deep Sea Res. 42(3), 307-330.

-Massutí, E., Morales-Nin, B., Lloris, D. (1996) Bathymetric distribution and recruitment patterns of *Phycis blennoides* (Pisces:Gadidae) from the slope of the norwestern Mediterranean. Sci.Mar. 60(4), 481-488.

Morales-Nin, B. Massutí, E., Stefanescu, C: (1996) Distribution and biology of *Alepocephalus rostratus* from the Mediterranean sea. J.Fish.Biol.48, 1097-1112.

-Maynou, F. &Cartes, J.E. (2000) Community structure of bathyal decapod crustaceans off south-west Balearic Islands (western Mediterranean): seasonality and regional patterns in zonation. J.Mar.Biol.Ass.U.K. 80, 789-798.

-Moranta, J., Stefanescu C., Massutí E., Morales-Nin B.& Lloris D. (1998) Fish community structure and depth related trends on the continental slope of the Balearic Islands (Algerian Basin, Western Mediterranean). Marine Ecology Progress Series 171, 233-246.

-Rowe G.T.(1971) Benthic biomass and surface productivity. In: Fertility of the sea, vol.2, J.D.Costlow Jr, editor, Gordon & Breach, New York, pp.97-122.

-Rowe G.T. & Menzies, R.J. (1969) Zonation of large benthic invertebrates in the deep-sea off the Carolinas. Deep-Sea Research 16, 531-537.

-Smith, C.R. & Hamilton, S.C: (1983) Epibenthic megafauna of a bathyal basin off southern California: patterns of abundance, biomass, and dispersion. Deep-Sea Res. 30A, 907-928.

-Stefanescu, C., Lloris, D., Rucabado, J. (1992) Deep-living demersal fishes in the Catalan Sea (western Mediterranean) below a depth of 1000 m. Jour Natural History 26, 197-213.

-Stefanescu, C., Lloris, D., Rucabado, J. (1993) Deep-sea fish assemblages in the Catalan Sea (western Mediterranean) below a depth of 1000 m. Deep-Sea Res 40, 695-707.

Table 1. Occurrence and mean individual weight (g) of fishes in the 46 trawl hauls on the W Mediterranean.

FAMILY	SPECIES	Ocurrences	Mean wt (g)
Scyliorinidae	*Galeus melastomus*	33	307.84
	Scyliorhinus canicula	8	89.80
Squalidae	*Centrophorus uyato*	1	4000.00
	Centroscymnus coelolepsis	13	992.77
	Dalatias licha	4	2175.38
	Etmopterus spinax	24	223.58
	Squalus blainvillei	1	100.00
Rajidae	*Raja naevus*	2	371.00
	Raja asterias	2	559.50
	Raja polystigma	1	220.00
Alepocephalidae	*Alepocephalus rostratus*	26	289.66
Gonostomidae	*Cyclothone braueri*	7	0.88
	Cyclothone pygmaea	5	0.83
Sternoptychidae	*Argyropelecus hemigymnus*	34	0.88
	Maurolicus muelleri	3	1.17
Chauliodontidae	*Chauliodus sloani*	15	32.88
Stomiidae	*Stomias boa*	17	6.02
Argentinidae	*Argentina sphiraena*	2	26.15
	Glossanodon leioglossus	4	21.33
Clorophthalmidae	*Clorophthalmus agassizii*	7	9.82
	Bathypterois mediterraneus	23	6.53
Myctophidae	*Benthosema glaciale*	11	1.06
	Lampanyctus crocodilus	34	11.76
	Myctophum punctatum	3	1.10
	Notoscopelus elongatus	3	1.22
	Electron rissoi	1	3.00
	Lobianchia dofleini	1	2.00
	Symbolophorus veranyi	1	1.00
	Borostomias antarticus	1	5.00
	Cerasthoscopelus maderensis	2	2.00
Paralepididae	*Notolepis rissoi*	6	1.83
Nemichthyidae	*Nemichthys scolopaceus*	1	13.00
Nettastomatidae	*Nettastoma melanurum*	20	98.78
Congridae	*Conger conger*	4	1518.25
Synaphobranchidae	*Dysomma brevirostre*	1	44.00
Notacanthidae	*Notacanthus bonapartei*	15	18.85
	Polyacanthonotus rissoanus	12	7.86
Macroramphosidae	*Macroramphosus scolopax*	4	9.75
Macrouridae	*Chalinura mediterranea*	15	8.34
	Coelorhynchus coelorhynchus	6	17.76
	Coelorhynchus labiatus	20	17.18
	Coryphaenoides guentheri	3	11.92
	Hymenocephalus italicus	16	9.93
	Nezumia aequalis	26	25.63
	Trachyrhyncus trachyrhyncus	5	207.07
Merluccidae	*Merluccius merluccius*	13	376.78

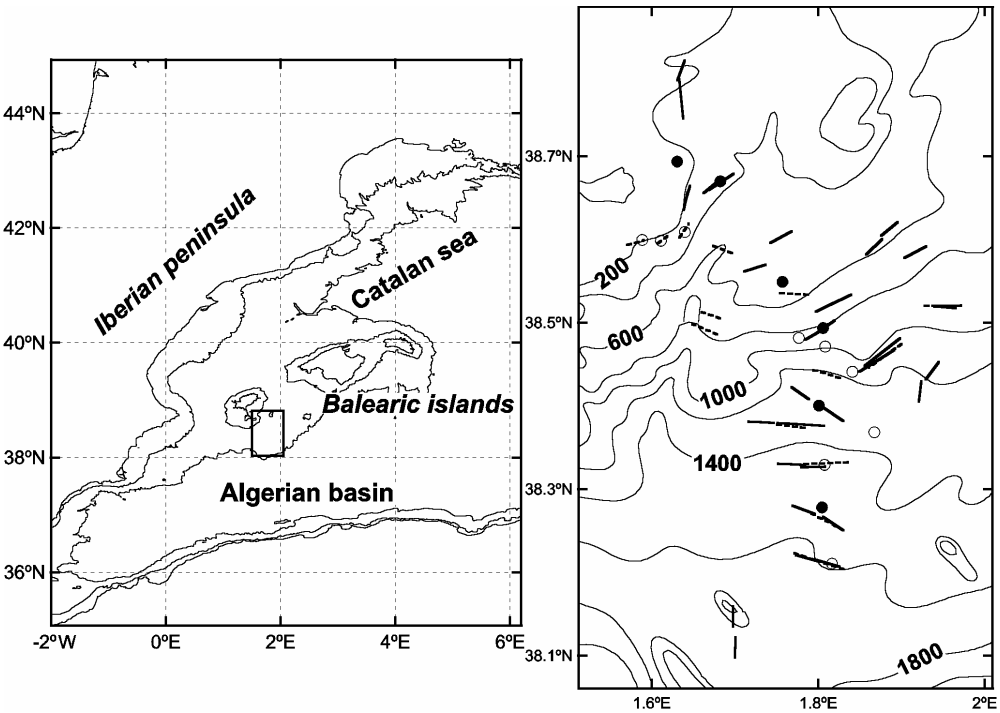
Table 1. (continued).

Gadiade	*Gadiculus argenteus*	9	4.99
	Micromesistius poutassou	10	153.20
	Trisopterus minutus capelanus	2	8.62
	Antonogadus megalokinodon	12	3.81
	Molva dipterygia macrophthalma	5	41.76
	Phycis blennoides	26	138.92
Moridae	*Laemonema sp.*	1	10.00
	Lepidion guentheri	3	365.33
	Lepidion lepidion	19	115.20
	Mora moro	16	538.91
Regalecidae	*Regalecus glesne*	1	0.40
Zeidae	*Zeus faber*	2	184.50
Caproidae	*Capros aper*	7	5.82
Apogonidae	*Epigonus denticulatus*	8	80.73
	Epigonus telescopus	2	732.14
Carangidae	*Trachurus picturatus*	1	196.00
	Trachurus trachurus	3	80.95
Mullidae	*Mullus surmuletus*	2	175.75
Sparidae	*Boops boops*	3	108.77
Trichiuridae	*Lepidopus caudatus*	11	58.14
Gobiidae	*Lesueurigobius friesii*	1	1.00
	Pomatoschistus minutus	1	1.00
Callionymidae	*Callionymus maculatus*	3	1.11
	Synchiropus phaeton	9	12.25
Bythitidae	*Cataetyx alleni*	7	1014
	Cataetyx laticeps	1	641.00
Trachichthyidae	*Hoplostethus mediterraneus*	15	40.76
Centrolophidae	*Centrolophus niger*	1	3000.00
Scorpaenidae	*Helicolenus dactylopterus*	12	24.64
	Scorpaena elongata	4	250.13
Triglidae	*Aspitrigla cuculus*	2	61.86
	Lepidotrigla cavillone	1	14.00
	Trigla lyra	7	34.18
Peristeiidae	*Peristedion cataphractum*	7	32.39
Liparidae	*Paraliparis leptochirus*	8	1.25
Citharidae	*Citharus linguatula*	1	42.00
Scophthalmidae	*Lepidorhombus boscii*	9	75.41
	Lepidorhombus wiffiagonis	2	12.96
Bothidae	*Arnoglossus laterna*	2	4.71
	Arnoglossus rueppelli	2	4.86
Cynoglossidae	*Symphurus ligulatus*	14	2.47
	Syimphurus nigrescens	9	5.40
Lophiidae	*Lophius budegassa*	2	208.50
	Lophius piscatorius	1	1136.00

Table 2. Occurrence and mean individual weight (g) of decapod crustaceans in the 46 trawl hauls on the W Mediterranean.

FAMILY	SPECIES	Ocurrences	Mean wt (g)
Aristeidae	*Aristaeomorpha foliacea*	3	13.77
	Aristeus antennatus	36	7.35
	Gennadas elegans	20	0.26
Peneaeidae	*Parapenaeus longirostris*	8	9.84
	Funchalia woodwardii	2	5.50
Solenoceridae	*Solenocera membranacea*	9	2.30
	Hymenopenaeus debilis	1	0.20
Sergestidae	*Sergestes arcticus*	19	0.33
	Sergestes henseni	6	0.92
	Sergia robusta	33	1.32
Stenopodidae	*Richardina fredericii*	5	0.17
Oplophoridae	*Acanthephyra eximia*	23	7.31
	Acanthephyra pelagica	24	5.10
Pasiphaeidae	*Pasiphaea multidentata*	19	5.97
	Pasiphaea sivado	5	1.42
Nematocarcinidae	*Nematocarcinus exilis*	16	0.76
Alpheidae	*Alpheus glaber*	5	0.42
Hippolitidae	*Ligur ensiferus*	1	3.02
Processidae	*Processa canaliculata*	7	1.77
	Processa nouveli	8	0.88
Pandalidae	*Chlorotocus crassicornis*	6	1.66
	Pandalina profunda	4	0.29
	Plesionika acanthonotus	24	1.88
	Plesionika antigai	5	1.21
	Plesionika edwardsi	5	4.91
	Plesionika gigliolii	8	2.23
	Plesionika heterocarpus	12	2.27
	Plesionika martia	13	6.11
	Plesionika narval	2	0.75
Crangonidae	*Philocheras echinulatus*	3	0.41
	Pontocaris lacazei	5	0.70
	Pontophilus norvegicus	12	0.65
Nephropidae	*Nephrops norvegicus*	7	22.99
Axiidae	*Calocaris macandreae*	9	0.41
Polychelidae	*Polycheles typhlops*	24	9.77
	Stereomastis sculpta	17	5.75
Diogenidae	*Dardanus arrosor*	1	20.00
Galatheidae	*Munida intermedia*	4	5.26
	Munida iris	7	5.49
	Munida tenuimana	27	2.76
Homolidae	*Paromola cuvieri*	12	264.96
Majidae	*Dorhynchus thomsoni*	3	0.47
	Macropodia longipes	7	0.68
Geryonidae	*Geryon longipes*	25	94.57
Portunidae	*Macropipus tuberculatus*	8	12.27
	Bathynectes maravigna	1	17.50
Goneplacidae	*Goneplax rhomboides*	4	1.23
Xanthidae	*Monodaeus couchi*	4	1.38

a)



b)

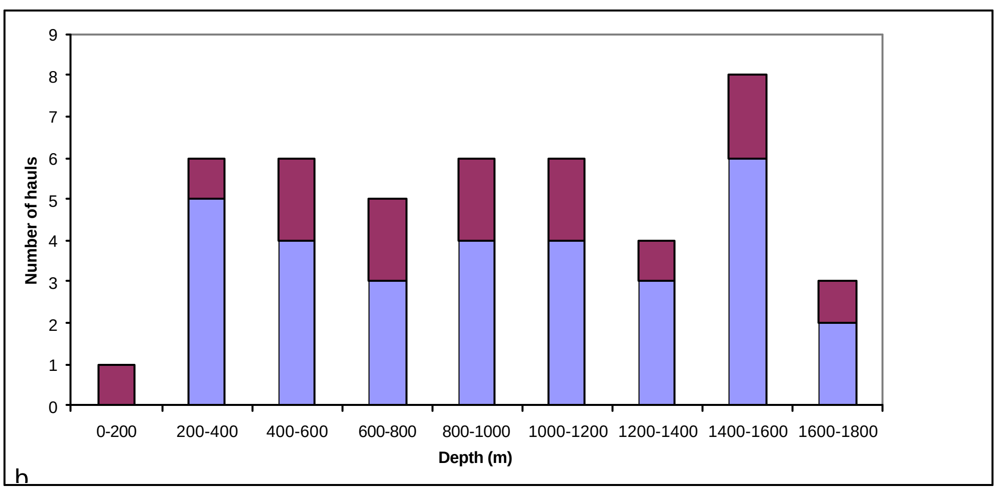


Fig.1. a) Map of the study area with indication of the trawl hauls position and CTD casts on both cruises. b) Distribution of the number of hauls by depth range. Lighter bars Quimera-I cruise, darker Quimera-II cruise.

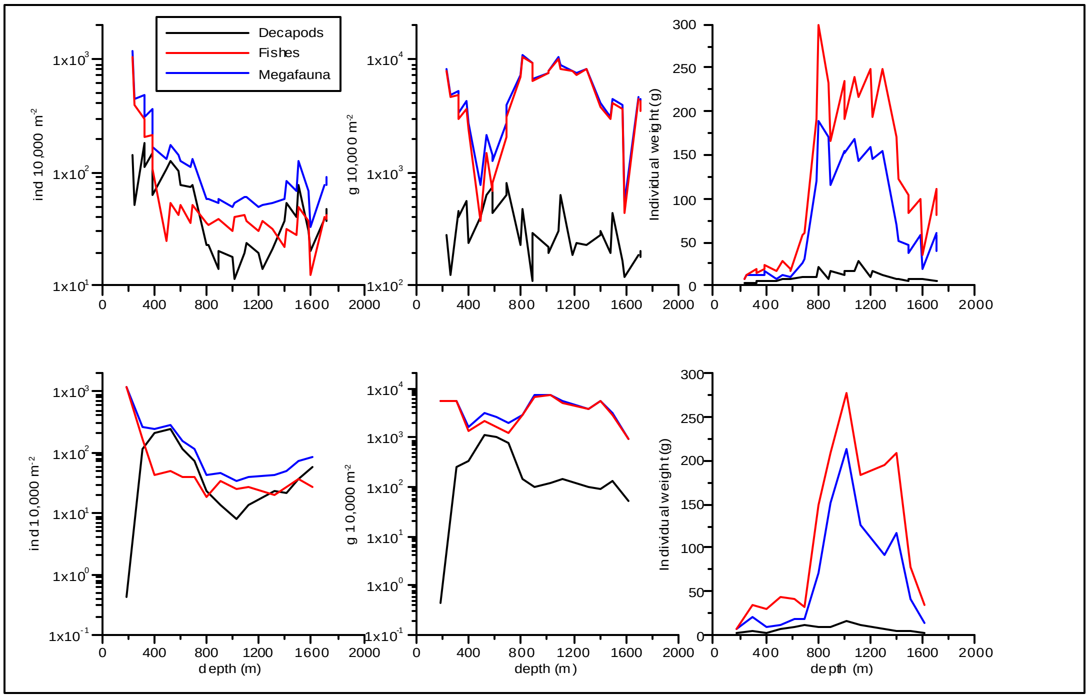


Fig.2. Depth distribution of the number of individuals (Nº 10,000 m^{-2}), biomass (g 10,000 m^{-2}) and individual weight (g) of fishes, decapod crustaceans and megafauna in Quimera-I (top) and Quimera-II (bottom) cruises.

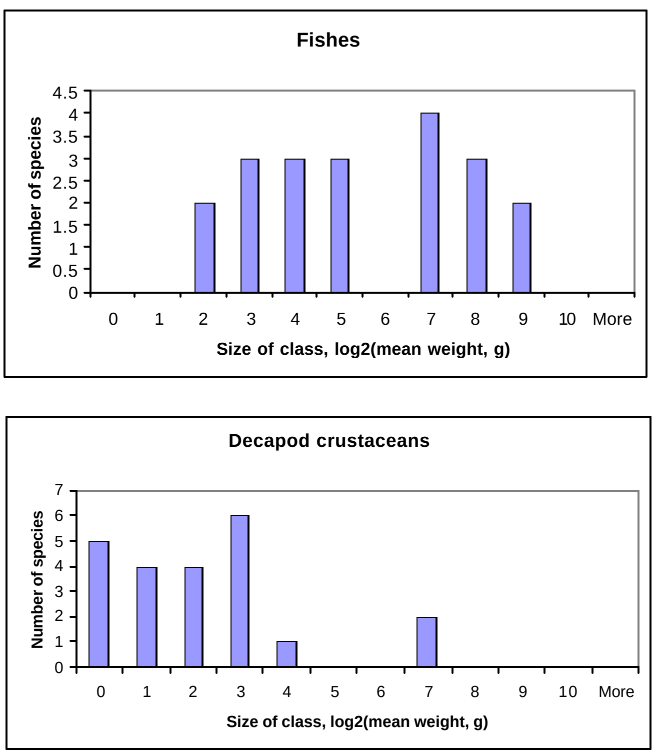


Fig.3. Species size spectra for decapod crustaceans and fishes.

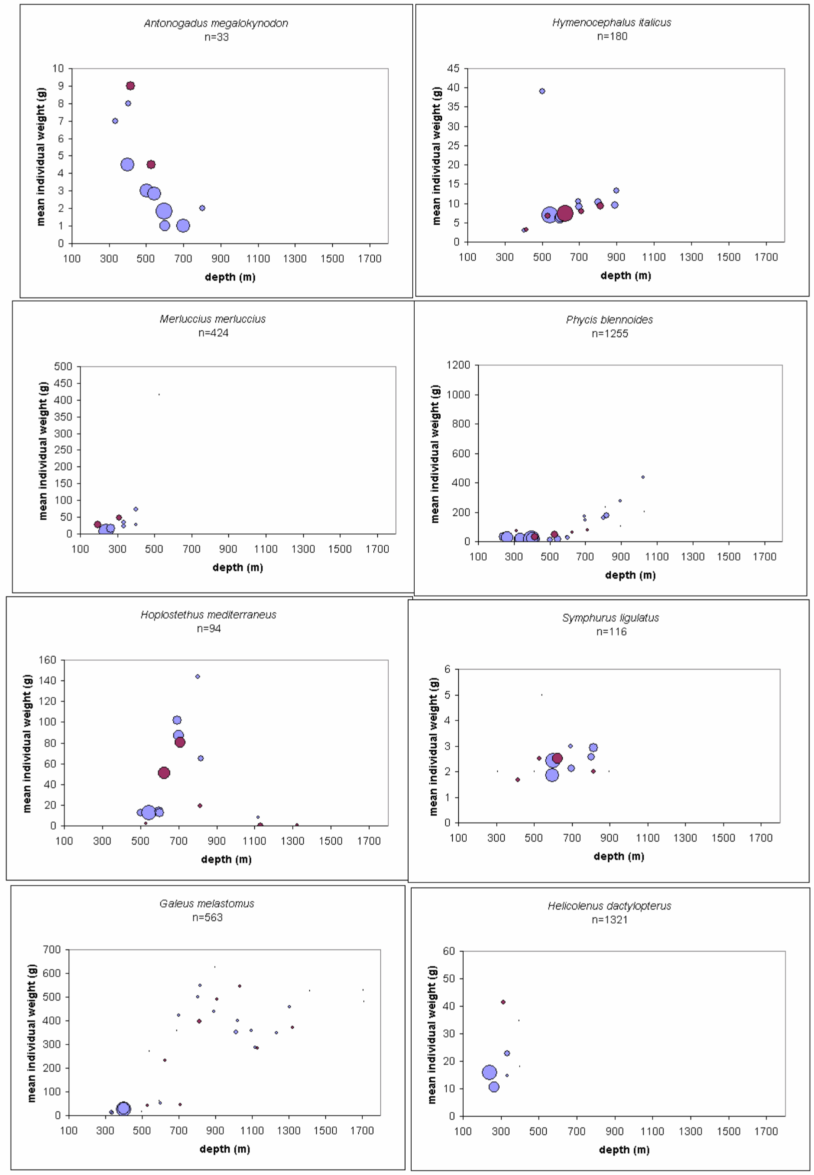


Fig.4. Bubbler plot showing the depth distribution of the mean individual weight of the fish species predominant at lower depths. n=number of analyzed individuals. The size of the bubble is proportional to the number of individuals present.

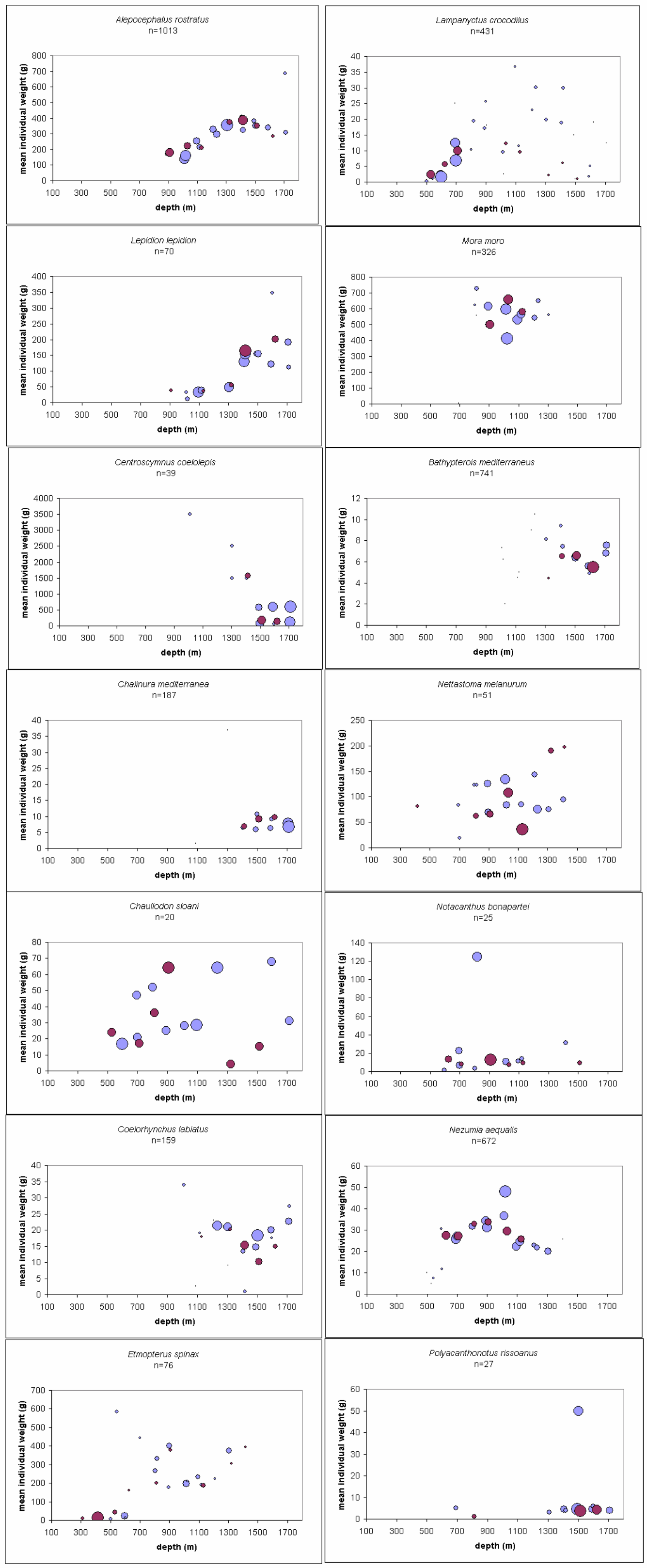


Fig.5. Bubbler plot showing the depth distribution of the mean individual weight of the fish species predominant at higher depths. n=number of analyzed individuals. The size of the bubble is proportional to the number of individuals present.

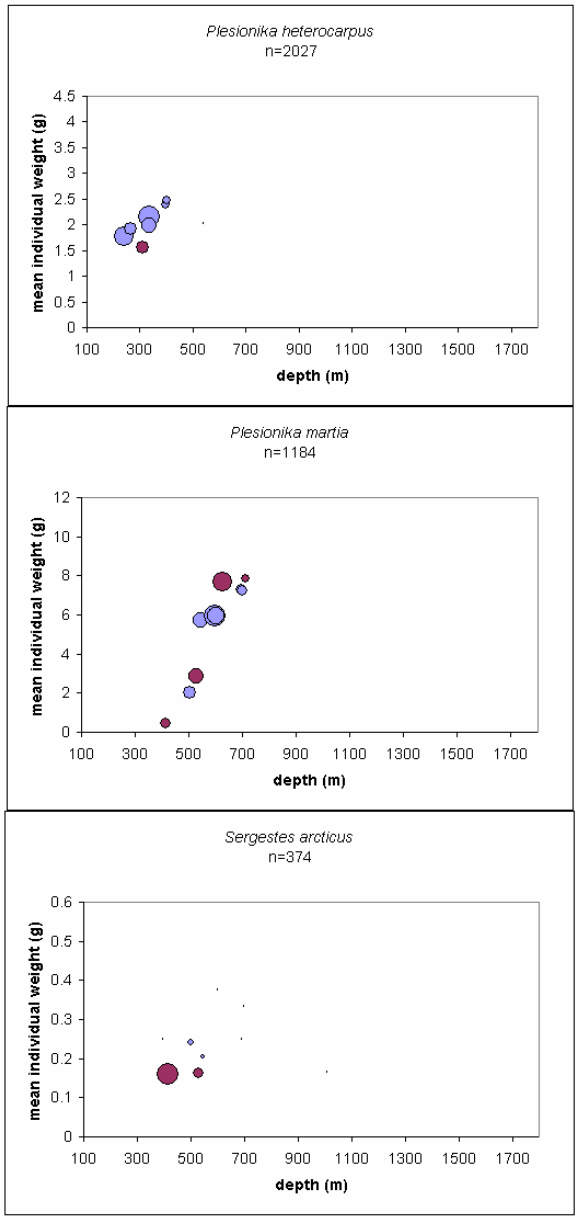


Fig.6. Bubbler plot showing the depth distribution of the mean individual weight of the decapod crustacean predominant at lower depths. n=number of analyzed individuals. The size of the bubble is proportional to the number of individuals present.

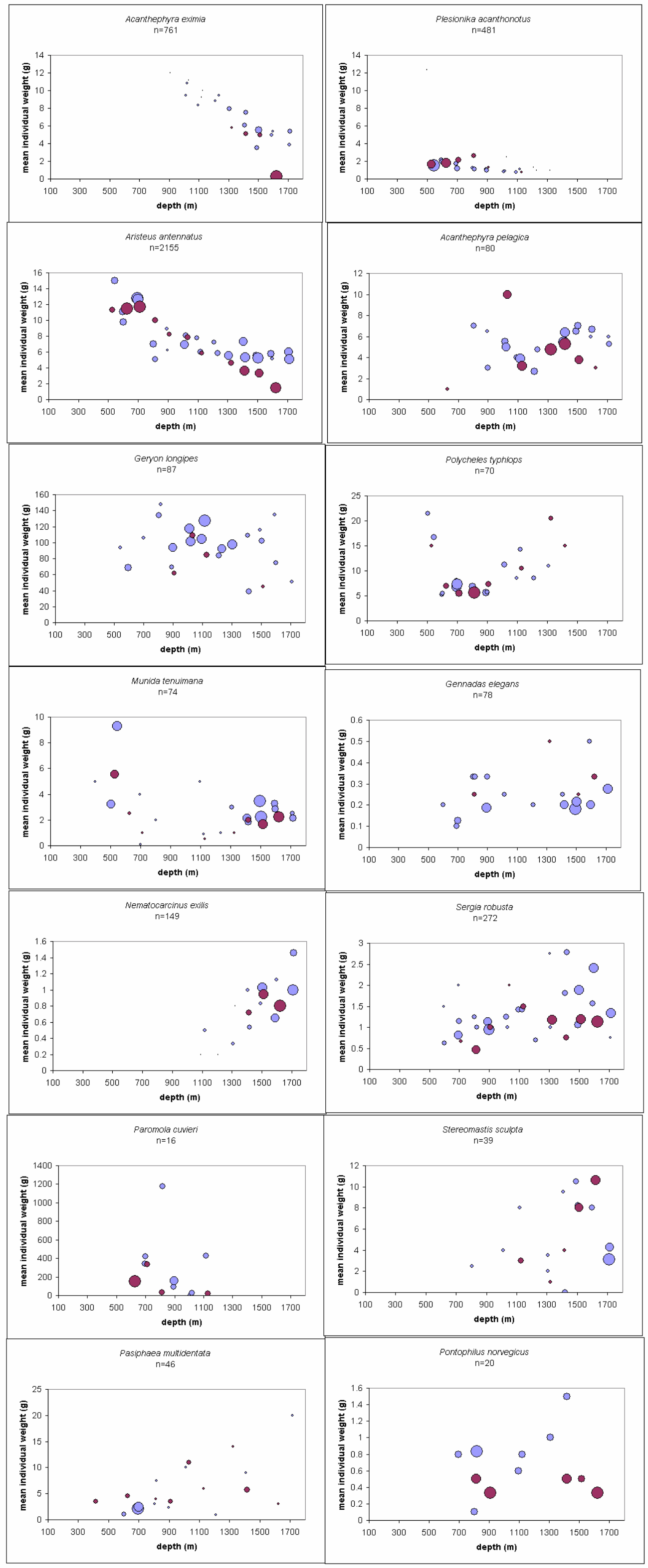


Fig.7. Bubbler plot showing the depth distribution of the mean individual weight of the decapod crustaceans predominant at higher depths. n=number of analyzed individuals. The size of the bubble is proportional to the number of individuals present.

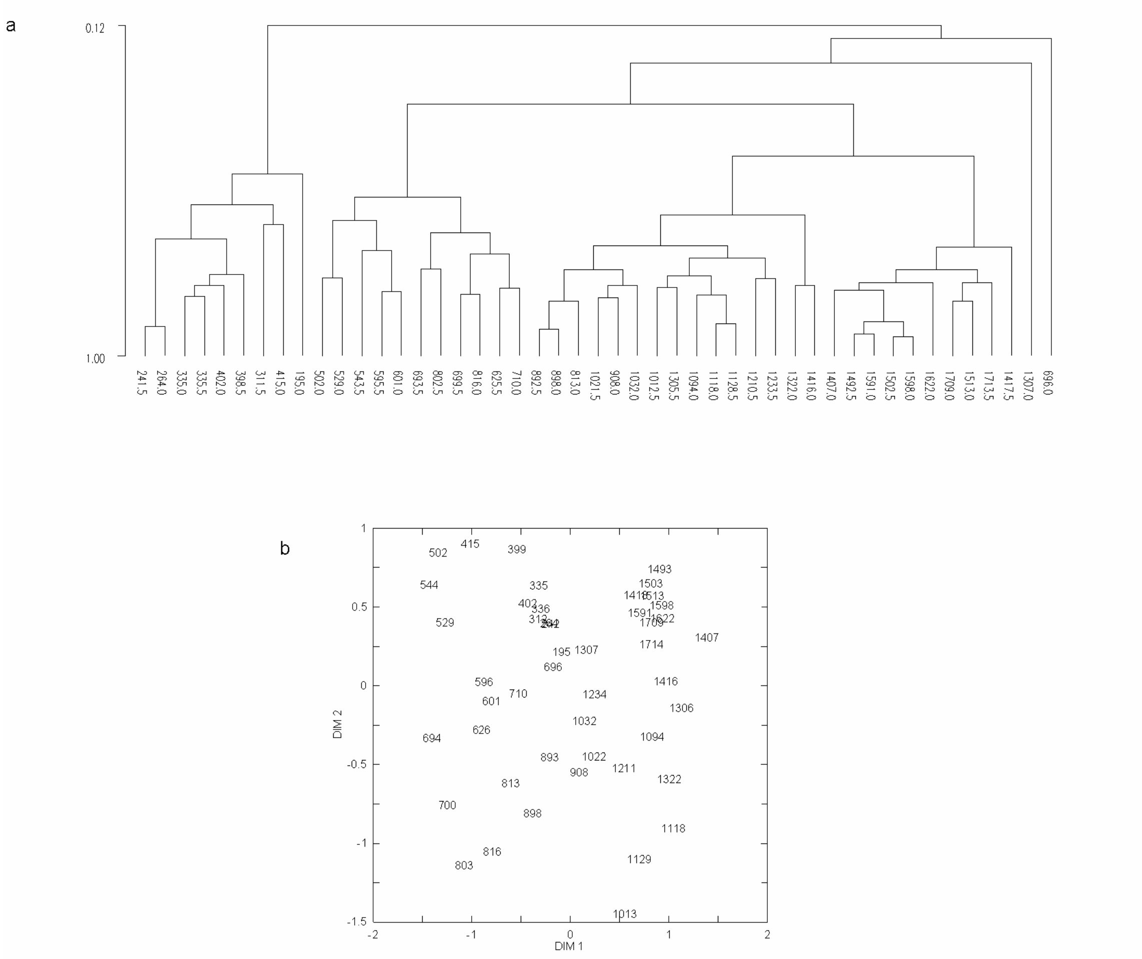


Fig.8. a) Cluster of the trawl hauls in function of the mean weight of fish and decapod crustaceans. b) MDS showing the grouping of the hauls.

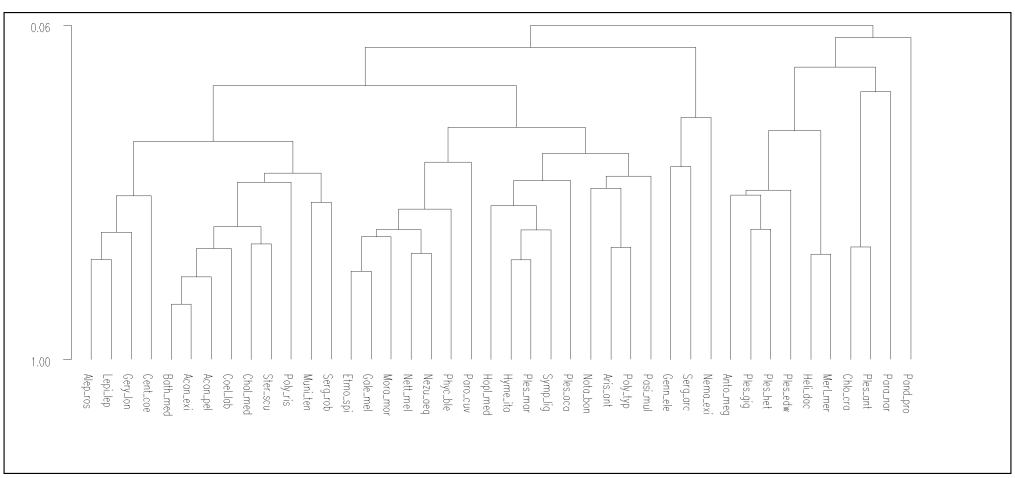


Fig.9. Cluster showing the ordination of fish and decapod crustaceans species in function of their mean weight.

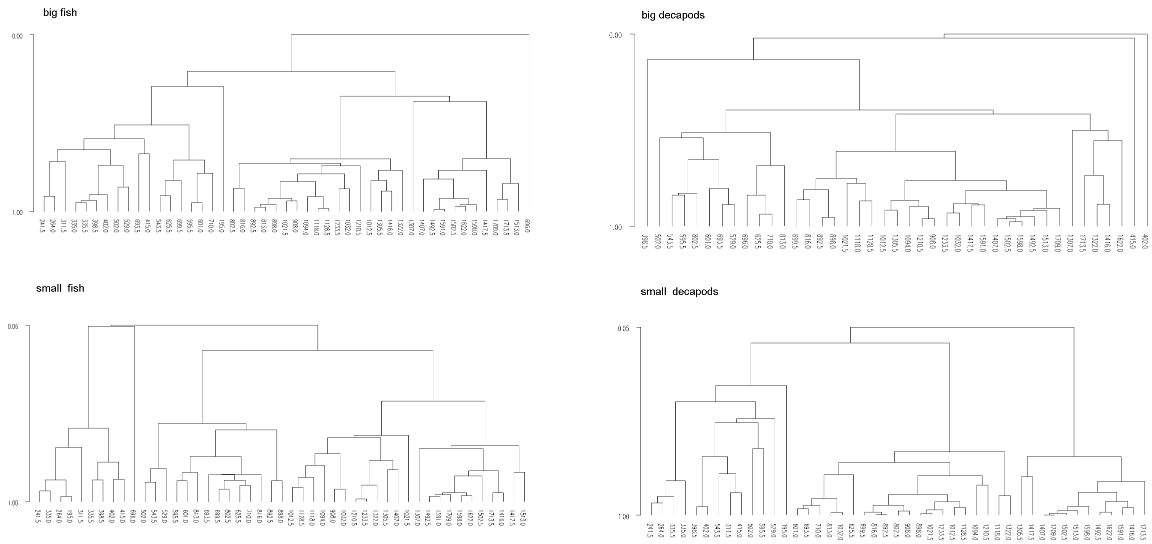


Fig.10. Ordenation in function of the mean weight below the median weight (MDS) of fishes (a), decapod crustaceans (c) and over the MDS for fishes (b) and decapod crustaceans (d).