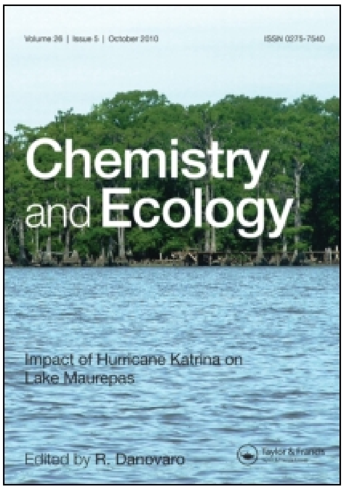

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The bathyal benthopelagic fauna in the north-western Ionian Sea: structure, patterns and interactions

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The bathyal benthopelagic fauna in the north-western Ionian Sea: structure, patterns and interactions

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The main knowledge acquired on the structure, patterns and interactions in the bathyal benthopelagic fauna in the north-western Ionian Sea is summarised in this article. Using faunal sampling along a depth range between 200 and 4000 m, a total of 41 cephalopods, 64 crustaceans and 183 fishes have been collected. Some are new findings for the study area and for many of the species the bathymetric distribution has been updated. Distinct faunal assemblages related to the upper slope (400–800 m), middle slope (800–1200 m) and lower slope (>1200 m) were identified using Abundance Biomass Comparison curves. Species abundance decreases across the bathymetric gradient, whereas the biomass increases to ~1000 m and then decreases again. Beyond this bathymetry, species richness, evenness and diversity index decrease with depth. The distribution pattern 'bigger–deeper' was observed in some species and 'smaller–deeper' in others. Roccella canyon and the Santa Maria di Leuca coral bank were investigated in relation to the distribution of fauna, highlighting migration phenomena in the former and a refuge effect in the latter. The effects of hydrographic conditions and fishing were also examined for the deep-water commercial shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus*.

Keywords: biodiversity; abundance; distribution; fish; crustaceans; cephalopods; sensitive habitat; north-western Ionian Sea

1. Introduction

More than 80% of the Mediterranean floor is deeper than 200 m (bathyal and abyssal zones), with a maximum depth of 5121 m in the eastern Ionian Sea (Matapan Deep) [1]. Because of the logistic/technical difficulties of exploration in the deep-sea environment, little information is available on the deep-water benthopelagic fauna [2,3]. In fact, although early explorations in the deep Mediterranean date back to the end of the 1800s [4], most of the known information on this fauna is limited to the depths from which biological resources are exploited, down to 800–1000 m [5–15]. Beyond these depths, some studies on the biodiversity and assemblages of

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benthopelagic species, represented by cephalopods, crustaceans and fish have been carried out both in the western Mediterranean [6,16–27] and in the eastern part [10,25,26,28–34].

From all these studies, depth was found to be the main factor in structuring assemblages. Considering the stability of the environmental parameters in the deep water of the Mediterranean Sea, the faunal zonation was attributed to the trophic resources available above and below depth boundaries, as well as to the particular stratified hydrological conditions [20,22–26,35]. However, changes in the faunal assemblages and communities also occur over the geographic gradient from the western to eastern Mediterranean. For example, differences in the deep-water ichthyofauna composition and abundance between the eastern and western Mediterranean seem to be due to the different trophic and hydrographic conditions, as well as to anthropogenic impacts, mainly in terms of deep-water fishing, on the two sides of the basin [36].

Usually, the deep Mediterranean biological communities are adapted to general oligotrophic conditions, with a local occurrence of higher productivity and biodiversity hotspots, the latter mainly due to submarine canyons, seamounts and cold-water coral mounds. These communities are very sensitive to human modifications, such as fishing, mostly because of the k-selective character of many constituting species [3,36].

However, considering the wide area covered by the bathyal and abyssal Mediterranean bottoms and the various limitations in sampling deep-water fauna [37], knowledge on the structure and distribution patterns of such fauna, as well as knowedge of interactions with habitats and human activities remains rather poor. Furthermore, considering the expansion of deep-sea fisheries in relation to overexploitation in shelf waters, and the evidence of large-scale human-induced environmental changes in the Mediterranean [38,39] even in deep waters, with effects both on meiofaunal biodiversity [40,41] and megafaunal fluctuations [42,43], the information available on the deep-water species assemblages and diversity can be considered a reference state providing information against which to evaluate changes.

The Ionian is the largest in terms of volume and the deepest sea in the Mediterranean. Biological resources in the Ionian Sea have long been exploited and, between the 1980s and 1990s, the sea experienced a major transition in the water mass structure and properties even at the greatest depths [44,45]. This basin shows a complex geomorphology mainly along the Calabrian–Sicily coasts, which are furrowed by active canyons transporting materials from the shelf break to the bathyal depth. Several slump deposits, which may also extend for many kilometres, have accumulated at the base of the continental slope by gravitational sliding [46]. The central sector of the Ionian Sea is represented by the Taranto Valley, an impressive NW–SE depression, easily recognisable down to depths exceeding 2200 m. The eastern sector is located between the Taranto Valley and Apulia. It is represented by a continental shelf with abrasion terraces and bioclastic calcareous deposits with several coral rocks. Along the Apulia coasts the distribution of living cold water corals has only been documented in the last decade [47,48], thanks to the increasing use of acoustic survey techniques and remotely operated vehicles (ROV). Clustered and isolated mound-like features, tens to a few hundreds of metres in length and no more than 25 m high, are located between 400 and 1000 m in depth within a broad area affected by down slope mass transport deposits. Isolated and patchy distributed colonies of *Lophelia pertusa* and *Madrepora oculata* are widespread on these mounds facing the main bottom current flow mainly coming from the Adriatic Sea.

Recent explorations in the bathyal environment of the Ionian Sea have been conducted within the framework of different projects, aiming to study the bathyal benthopelagic fauna less than 800 m in depth, where fishing activity occurs, and below that depth, where the grounds could be considered ‘virgin’, owing to the absence of fishing activity. These projects have increased knowledge on the deep-water fauna, in terms of structure, distribution patterns and interactions with habitat and human activities. A synthesis of the most important results, integrated with further analyses, is reported in this article.

2. Materials and methods

Data were collected during experimental bottom trawl surveys carried out in the north-western Ionian Sea (Figure 1) as part of a number of study projects financed by the Italian Government and the EU: GRUND [49], RED SHRIMPS [50], MEDITS [51], DESEAS [3], APLABES [52] and GAVIS [53] (Table 1).

The sampling design adopted in each survey was random-stratified. The horizontal and vertical opening of all types of trawl nets was measured using the SCANMAR acoustic system [54,55]. All specimens taken in each haul were identified. For each individual, the following data were taken: length, according to species, to the nearest mm and body weight to the nearest 0.1 g.

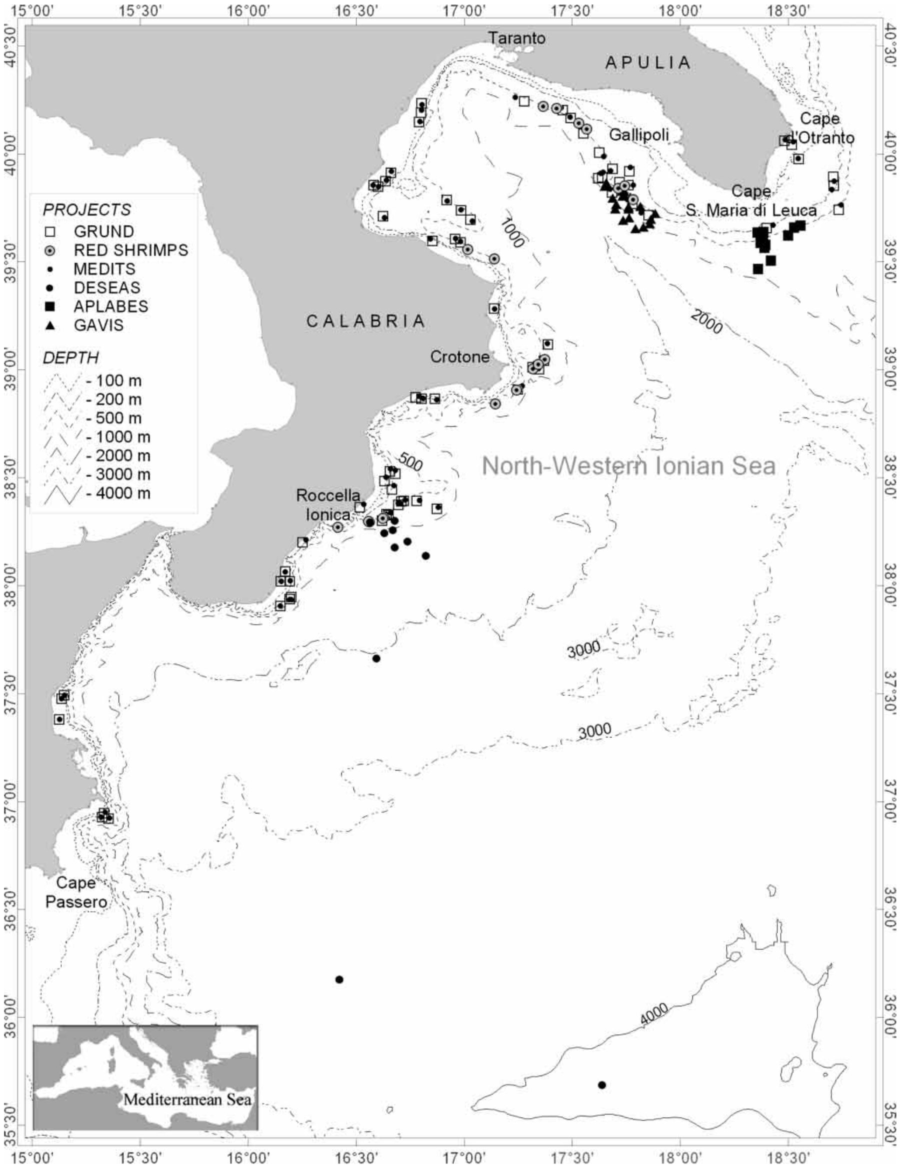

Figure 1. Map of the study area in the north-western Ionian Sea.

Table 1. Study projects carried out in the north-western Ionian Sea with an indication of geographic area, study period, depth range, gear and mesh size.

Projects	Geographic area	Study period	Depth range (m)	Gear	Stretched mesh (in the codend; mm)
GRUND	Cape Otranto (Apulia) to Cape Passero (Sicily)	1985–2008	10–800	Commercial trawl net	40
RED SHRIMPS	Cape Otranto (Apulia) to Roccella Ionica (Calabria)	1993–1995	250–750	Commercial trawl net	40
MEDITS	Cape Otranto (Apulia) to Cape Passero (Sicily)	1994–2008	10–800	Experimental trawl net	20
DESEAS	Balearic, western Ionian, eastern Ionian Sea	June 2001	600–4000	Otter trawl Maireta net	20
APLABES	Gallipoli, S. Maria di Leuca coral area	September–October 2005	300–800	Commercial trawl net	40
GAVIS	Gallipoli	April, May, June, September 2006	400–1200	Otter trawl Maireta net	20

Abundance data were standardised to km^2 for subsequent numerical processing. In particular, the density (N·km^{-2}) and biomass (kg·km^{-2}) indices were computed using the number and weight of the individuals for each haul swept area carried out across the whole bathymetric gradient investigated during DESEAS and GAVIS. The swept area was estimated according to the wing spread of the net (horizontal opening), the speed of the vessel and the haul duration [56].

The structure of faunal assemblages across the bathymetric gradient of 400–4000 m was analysed using Abundance Biomass Comparison (ABC) curves [57,58]. ABC curves were computed considering standardised data of numerical abundance and biomass of fish, crustaceans and cephalopods with respect to three depth ranges, according to the faunal assemblages detected in the upper slope (400–800 m), middle slope (800–1200 m) and lower slope ($>$1200 m) throughout the Mediterranean [23,24,26].

Univariate ecological indices (Margaleff richness d, Shannon–Wiener diversity index H′, Pielou’s evenness J) [59] were also computed across the whole bathymetric gradient investigated during the DESEAS and GAVIS surveys and their changes with depth were evaluated using regression analysis.

All surveys carried out in the north-western Ionian Sea gave the opportunity to record new species for the area and to update the depth range for some others. Depth-size trends for 10 species were also determined by means of regression analysis between the geometric mean of each sample versus depth.

For the two deep-water shrimps, *Aristaeomorpha foliacea* and *Aristeus antennatus*, abundance indices (N·km^{-2} and kg·km^{-2}) were estimated for the period 1995–2005 using data from the GRUND and MEDITS surveys. The temporal trends observed for these indices were correlated (Spearman’s rank correlation) with the trend in temperature and salinity detected in the studied area over the same period [60]. In addition, the length/frequency distributions of these two shrimps were calculated from 2001 to 2005 to highlight the fishing effect on these exploited populations.

In the Ionian basin there are two typically bathyal habitats, namely canyons, along the Calabrian coasts, and the Santa Maria di Leuca coral bank. In the first, the shallowest depth findings of *A. antennatus* and *A. foliacea* (144 m) were recorded during hauls carried out only during the night at the head of the Roccella Jonica canyon [61]. Tagging experiments were carried out on *A. antennatus* collected in this habitat [62,63]. These were the first experiments in the Mediterranean Sea on the bathyal fauna and were conducted on May 1998. About the second habitat, abundance in number and weight of the bathyal fauna collected inside and outside the coral bank was estimated. The size structures were computed for the most abundant species which displayed the greatest dissimilarity in abundance between the two study areas [64]. Further differences between the coral versus non-coral areas are supported in this article using a box-plot of the sizes in some fish species collected inside and outside the S. Maria di Leuca coral habitat.

3. Results

3.1. *Structure*

Considering depths >200 m, a total of 41 cephalopods, 64 crustaceans and 183 fishes (26 chondroichthyes and 157 teleosts) were collected in the north-western Ionian Sea as part of the above-mentioned studies (Table 2).

ABC plots of this fauna showed a higher curve for abundance than for biomass in the upper slope (400–800 m), a higher curve for biomass than abundance in the middle slope (800–1200 m) and the intersection of the two curves for the species collected in the lower slope (>1200 m) (Figure 2).

Considering the density, the greater number of hauls carried out during GAVIS provided a decreasing trend with depth within the bathymetric gradient of 400–1200 m, whereas the smaller number of hauls conducted during DESEAS showed an increase within 1500 m and then a marked reduction at the greatest depths. For the biomass, both studies showed an increase as far as the middle slope. A marked decrease in the lower slope was shown during the DESEAS project (Figure 3).

With regard to the univariate ecological indices in the depth range of 400–1200 m, the richness index (d) and eveness index (J) decreased and increased significantly with depth, respectively, although the Shannon–Wiener index (H') did not show any trend. Considering depths between 400 and 4000 m, all these indices decreased significantly with depth although the patterns observed within 1200 m were confirmed, that is the decrease in d, the increase in J and the constancy of H' (Figure 4).

3.2. *Patterns*

The new findings and depth records of the crustaceans and fishes collected in the north-western Ionian Sea are reported in Figure 5. With regard to crustaceans, *Chaceon mediterraneu*s and *Nematocarcinus exilis* represent new findings for the study area [25]. For the two most important commercial deep-water shrimps in the Mediterranean, the new maximum depth of finding was 1145 m for *Aristaeomorpha foliacea* and 3300 m for *Aristeus antennatus* [65]. In addition, concerning fishes, *Cataetyx laticeps*, *Coelorinchus mediterraneus*, *Coryphaenoides guentheri*, *Coryphaenoides mediterraneus* and *Lepidion lepidion* represent new findings in the study area [33].

Regarding the depth-size trends, *A. antennatus* and *Polycheles typhlops* exhibited a smaller–deeper trend, whereas a bigger–deeper distribution pattern was shown in *Nephrops norvegicus*, *Plesionika martia*, *Galeus melastomus*, *Mora moro*, *Nezumia sclerorhynchus*, *Phycis blennoides* and *Trachyrincus scabrus*. For *Bathypterois mediterraneus* no significant trend was shown in the broader depth range of 800–3300 m (Figure 6).

3.3. *Interactions*

The two bathyal shrimps, *A. antennatus* and *A. foliacea*, represent the most important deep-water fisheries resources in the north-western Ionian Sea. The former is generally more abundant than the latter. However, during the period 2000–2004 *A. foliacea* was found to be more abundant than

Table 2. Cephalopods, crustaceans, chondroichthyes and teleosts caught in the north-western Ionian Sea at depths below 200 m.

Cephalopods
Abralia verany (Rüppell, 1844)
Abraliopsis pfefferi Joubin, 1896
Alloteuthis media (Linnaeus, 1758)
Alloteuthis subulata (Lamarck, 1798)
Ancistrocheirus lesueurii (D'Orbigny, 1842)
Ancistroteuthis lichtensteinii (Férussac, 1835)
Argonauta argo Linnaeus, 1758
Brachioteuthis nisei (Steenstrup, 1882)
Chiroteuthis veranii (Férussac, 1835)
Ctenopteryx sicula (Verany, 1851)
Eledone cirrhosa (Lamarck, 1798)
Eledone moschata (Lamarck, 1798)
Galiteuthis armata Joubin, 1898
Heteroteuthis dispar (Rüppell, 1844)
Histioteuthis bonnellii (Férussac, 1835)
Histioteuthis reversa (Verrill, 1880)
Illex coindetii (Verany, 1839)
Loligo forbesii Steenstrup, 1856
Loligo vulgaris Lamarck, 1798
Neorossia caroli (Joubin, 1902)
Octopoteuthis sicula Rüppell, 1844
Octopus defilippi Verany, 1851
Octopus macropus Risso, 1826
Octopus salutii Verany, 1839
Octopus vulgaris Cuvier, 1797
Onychoteuthis banksii (Leach, 1817)
Pteroctopus tetracirrhus (Celle Chiaje, 1830)
Pyroteuthis margaritifera (Rüppell, 1844)
Rondeletiola minor (Naef, 1912)
Rossia macrosoma (Celle Chiaje, 1830)
Scaeurgus unicirrhus (Celle Chiaje, 1841)
Sepia elegans Blainville, 1827
Sepia officinalis Linnaeus, 1758
Sepia orbignyana Férussac, 1826
Sepietta oweniana (D'Orbigny, 1841)
Sepiola intermedia Naef, 1912
Sepiola ligulata Naef, 1912
Sepiola robusta Naef, 1912
Sepiola rondeletii Leach, 1817
Todarodes sagittatus (Lamarck, 1798)
Todaropsis eblanae (Ball, 1841)

Crustaceans
Acanthephyra eximia S.I. Smith, 1884
Acanthephyra pelagica (Risso, 1816)
Aegeon lacazei (Gourret, 1887)
Alpheus glaber (Olivi, 1792)
Aristaeomorpha foliacea (Risso, 1827)
Aristeus antennatus (Risso, 1816)
Atelecyclus rotundatus (Olivi, 1792)
Bathynectes maravigna (Prestandrea, 1839)
Calappa granulata (Linnaeus, 1758)
Calappa rissoana Pastore, 1995
Calappa tuerkayana Pastore, 1995
Chaceon mediterraneus Manning & Holthuis, 1989
Chlorotocus crassicornis (A. Costa, 1871)
Ebalia nux A. Milne-Edwards, 1883
Gennadas elegans S.I. Smith, 1882
Geryon longipes A. Milne-Edwards, 1882
Goneplax rhomboides (Linnaeus, 1758)
Homola barbata (J.C. Fabricius, 1793)
Inachus communissimus Rizza, 1839
Inachus dorsettensis (Pennant, 1777)
Latreillia elegans Roux, 1830
Ligur ensiterus (Risso, 1816)
Liocarcinus depurator (Linnaeus, 1758)
Lophogaster typicus M. Sars, 1857
Macropipus tuberculatus (Roux, 1830)
Macropodia longipes (A. Milne Edwards & Bouvier, 1899)
Macropodia rostrata (Linnaeus, 1761)
Medorippe lanata (Linnaeus, 1767)
Monodaeus couchii (Couch, 1851)
Munida curvimana A. Milne-Edwards & Bouvier, 1894
Munida intermedia A. Milne-Edwards & Bouvier, 1899
Munida rutllanti Zariquiey Alvarez, 1952
Munida tenuimana G.O. Sars, 1872
Nematocarcinus exilis Bate, 1888
Nephrops norvegicus (Linnaeus, 1758)
Parapenaeus longirostris (Lucas, 1846)
Paromola cuvieri (Risso, 1816)
Parthenope macrochelos (Herbst, 1790)
Pasiphaea multidentata Esmark, 1866
Pasiphaea sivado (Risso, 1816)
Penaeus kerathurus (Forssakal, 1775)
Periclimenes granulatus Holthuis, 1950
Philocheras echinulatus (M. Sars, 1861)
Plesionika acanthonotus (S.I. Smith, 1882)
Plesionika antigai Zariquiey Alvarez, 1955
Plesionika edwardsii (Brandt, 1851)
Plesionika gigliolii (Senna, 1903)
Plesionika heterocarpus (A. Costa, 1871)
Plesionika martia (A. Milne Edwards, 1883)
Plesionika narval (J.C. Fabricius, 1787)
Polycheles typhlops Heller, 1862
Pontophilus spinosus (Leach, 1815)
Pontophyilus norvegicus (M. Sars, 1861)
Processa canaliculata Leach, 1815
Pseudosquillopsis cerisii (Roux, 1828)
Rissoides desmaresti (Risso, 1816)
Rissoides pallidus (Giesbrecht, 1910)
Rochinia rissoana (Roux, 1828)
Scyllarus pygmaeus (Bate, 1888)
Sergestes arachnidopus (Cocco, 1832)
Sergestes arcticus Krayer, 1855
Sergia robusta (S.I. Smith, 1882)
Solenocera membranacea (Risso, 1816)
Squilla mantis (Linnaeus, 1758)

Chondroichthyes
Centrophorus granulosus (Bloch & Schneider, 1801)
Centrophorus uyato (Rafinesque, 1810)
Chimaera monstrosa Linnaeus, 1758
Dalatias licha (Bonnaterre, 1788)
Dipturus batis (Linnaeus, 1758)
Dipturus oxyrinchus (Linnaeus, 1758)
Etmopterus spinax (Linnaeus, 1758)
Galeus melastomus Rafinesque, 1810
Gymnura altavela (Linnaeus, 1758)
Heptranchias perlo (Bonnaterre, 1788)
Hexanchus griseus (Bonnaterre, 1788)
Leucoraja circularis (Couch, 1838)

(*Continued*)

Table 2. Continued.

Leucoraja fullonica (Linnaeus, 1758)
Mustelus mustelus (Linnaeus, 1758)
Oxynotus centrina (Linnaeus, 1758)
Raja asterias Delaroche, 1809
Raja clavata Linnaeus, 1758
Raja miraletus Linnaeus, 1758
Raja montagui Fowler, 1910
Rostroraja alba (Lacepède, 1803)
Scyliorhinus canicula (Linnaeus, 1758)
Somniosus rostratus (Risso, 1827)
Squalus blainvillei (Risso, 1826)
Torpedo marmorata Risso, 1758
Torpedo nobiliana Bonaparte, 1835
Torpedo torpedo (Linnaeus, 1758)
Epigonus telescopus (Risso, 1810)
Acantholabrus palloni (Risso, 1810)
Argentina sphyraena Linnaeus, 1758
Argyropelecus hemigymnus Cocco, 1829
Ariosoma balearicum (Celaroche, 1809)
Arnoglossus laterna (Walbaum, 1792)
Arnoglossus rueppelli (Cocco, 1844)
Arnoglossus thori Kyle, 1913
Aspitrigla cuculus (Linnaeus, 1758)
Aulopus filamentosus (Bloch, 1792)
Auxis rochei rochei (Risso, 1810)
Bathophilus nigerrimus Giglioli, 1884
Bathypterois mediterraneus Bauchot, 1962
Benthocometes robustus (Goode & Bean, 1886)
Benthosema glaciale (Reinhardt, 1837)
Blennius ocellaris Linnaeus, 1758
Boops boops (Linnaeus, 1758)
Bothus podas (Celaroche, 1809)
Buglossidium luteum (Risso, 1810)
Callanthias ruber (Rafinesque, 1810)
Callionymus maculatus Rafinesque, 1810
Callionymus risso Le Sueur, 1814
Capros aper (Linnaeus, 1758)
Caranx rhonchus Geoffroy Saint-Hilaire, 1817
Carapus acus (Brünnich, 1768)

Teleosts
Cataetyx laticeps Koefoed, 1927
Centracanthus cirrus Rafinesque, 1810
Centrolophus niger (Gmelin, 1789)
Cepola macrophthalma Linnaeus, 1758
Ceratoscopelus maderensis (Lowe, 1839)
Chauliodus sloani Schneider, 1801
Chelidonichthys lastoviza (Bonnaterre, 1788)
Chelidonichthys lucerna (Linnaeus, 1758)
Chelidonichthys obscurus (Bloch & Schneider, 1801)
Chlopsis bicolor Rafinesque, 1810
Chlorophthalmus agassizii Bonaparte, 1840
Cichlasoma bimaculatum (Linnaeus, 1758)
Ciclothone braueri Jespersen & Tåning, 1926
Citharus linguatula (Linnaeus, 1758)
Coelorinchus caelorhincus (Risso, 1810)
Coelorinchus mediterraneus Iwamoto & Ungaro, 2002
Conger conger (Linnaeus, 1758)
Coryphaena hippurus Linnaeus, 1758
Coryphaenoides guentheri (Vaillant, 1888)
Coryphaenoides mediterraneus (Giglioli, 1893)
Cubiceps gracilis (Lowe, 1843)
Dalophis imberbis (Celaroche, 1809)
Deltentosteus quadrimaculatus (Valenciennes, 1837)
Dentex dentex (Linnaeus, 1758)
Diaphus metopoclampus (Cocco, 1829)
Diaphus holti Tåning, 1918
Diaphus rafinesquei (Cocco, 1838)
Dysomma brevirostre (Facciolà, 1887)
Echelus myrus (Linnaeus, 1758)
Echiodon dentatus (Cuvier, 1829)
Elates ransonnetii (Steindachner, 1876)
Electrona risso (Cocco, 1829)
Engraulis encrasicolus (Linnaeus, 1758)
Epigonus constanciae (Giglioli, 1880)
Epigonus denticulatus Deuzeide, 1950
Eutrigla gurnardus (Linnaeus, 1758)
Evermannella balbo (Risso, 1820)
Gadella maraldi (Risso, 1810)
Gadiculus argenteus argenteus Guichenot, 1850
Gaidropsarus biscayensis (Collett, 1890)
Gaidropsarus mediterraneus (Linnaeus, 1758)
Glossanodon leioglossus (Valenciennes, 1848)
Gnathophis mystax (Celaroche, 1809)
Gobius niger Linnaeus, 1758
Gonichthys cocco (Cocco, 1829)
Gonostoma denudatum Rafinesque, 1810
Grammonus ater (Risso, 1810)
Helicolenus dactylopterus dactylopterus (Delaroche, 1809)
Hoplostethus mediterraneus mediterraneus Cuvier, 1829
Hygophum benoiti (Cocco, 1838)
Hygophum hygomii (Lütken, 1892)
Hymenocephalus italicus Giglioli, 1884
Ichthyococcus ovatus Cocco, 1838
Lampanyctus crocodilus (Risso, 1810)
Lepidion lepidion (Risso, 1810)
Lepidopus caudatus (Euphrasen, 1788)
Lepidorhombus boscii (Risso, 1810)
Lepidorhombus whiffiagonis (Walbaum, 1792)
Lepidotrigla cavillone (Lacepède, 1801)
Leusueurigobius friesii (Malm, 1874)
Lesueurigobius suerii (Risso, 1810)
Lobianchia dofleini (Zugmayer, 1911)
Lobianchia gemellarii (Cocco, 1838)
Lophius budegassa Spinola, 1807
Lophius piscatorius Linnaeus, 1758
Macroramphosus scolopax (Linnaeus, 1758)
Maurolicus muelleri (Gmelin, 1789)
Merlangius merlangus (Linnaeus, 1758)
Merluccius merluccius (Linnaeus, 1758)
Micromesistius poutassou (Risso, 1826)
Molva dipterygia (Pennant, 1784)
Monochirus hispidus Rafinesque, 1814
Mora moro (Risso, 1810)
Mullus barbatus barbatus Linnaeus, 1758
Mullus surmuletus Linnaeus, 1758
Myctophum punctatum Rafinesque, 1810
Nansenia oblita (Facciolà, 1887)
Nemichthys scolopaceus Richardson, 1848
Nettastoma melanurum Rafinesque, 1810
Nezumia sclerorhynchus (Valenciennes, 1838)
Notacanthus bonaparte Risso, 1840

(*Continued*)

Table 2. Continued.

Notoscopelus elongatus (Costa, 1844)
Ophichthus rufus (Rafinesque, 1810)
Ophidion barbatum Linnaeus, 1758
Ophidion rochei Müller, 1845
Ophisurus serpens (Linnaeus, 1758)
Pagellus acarne (Risso, 1826)
Pagellus bogaraveo (Brünnich, 1768)
Pagellus erythrinus (Linnaeus, 1758)
Paralepis speciosa Bellotti, 1878
Peristedion cataphractum (Linnaeus, 1758)
Phycis blennoides (Brünnich, 1768)
Phycis phycis (Linnaeus, 1766)
Polyprion americanum (Bloch & Schneider, 1801)
Sardina pilchardus (Walbaum, 1792)
Schedophilus ovalis (Cuvier, 1833)
Scomber japonicus Houttuyn, 1782
Scomber scombrus Linnaeus, 1758
Scorpaena elongata Cadenat, 1943
Scorpaena notata Rafinesque, 1810
Scorpaena porcus Linnaeus, 1758
Scorpaena scrofa Linnaeus, 1758
Seriola dumerili (Risso, 1810)
Serranus cabrilla (Linnaeus, 1758)
Serranus hepatus (Linnaeus, 1758)
Solea solea (Linnaeus, 1758)
Sphoeroides pachygaster (Müller & Troschel, 1848)
Sphyraenas phyraena (Linnaeus, 1758)
Spicara maena (Linnaeus, 1758)
Spicara smaris (Linnaeus, 1758)
Sprattus sprattus sprattus (Linnaeus, 1758)
Stomias boa boa (Risso, 1810)
Sudis hyalina Rafinesque, 1810
Symbolophorus veranyi (Moreau, 1888)
Symphurus ligulatus (Cocco, 1844)
Symphurus nigrescens Rafinesque, 1810
Synchiropus phaeton Günther, 1861
Syngnathus typhle Linnaeus, 1758
Synodus saurus (Linnaeus, 1758)
Tetragonurus cuvieri (Risso, 1810)
Trachinus draco Linnaeus, 1758
Trachinus radiatus Cuvier, 1829
Trachurus mediterraneus (Steindachner, 1868)
Trachurus picturatus (T.E. Bowdich, 1825)
Trachurus trachurus (Linnaeus, 1758)
Trachyrincus scabrus (Rafinesque, 1810)
Trigla lyra Linnaeus, 1758
Trisopterus minutus (Linnaeus, 1758)
Uranoscopus scaber Linnaeus, 1758
Vinciguerria attenuata (Cocco, 1838)
Zeus faber Linnaeus, 1758

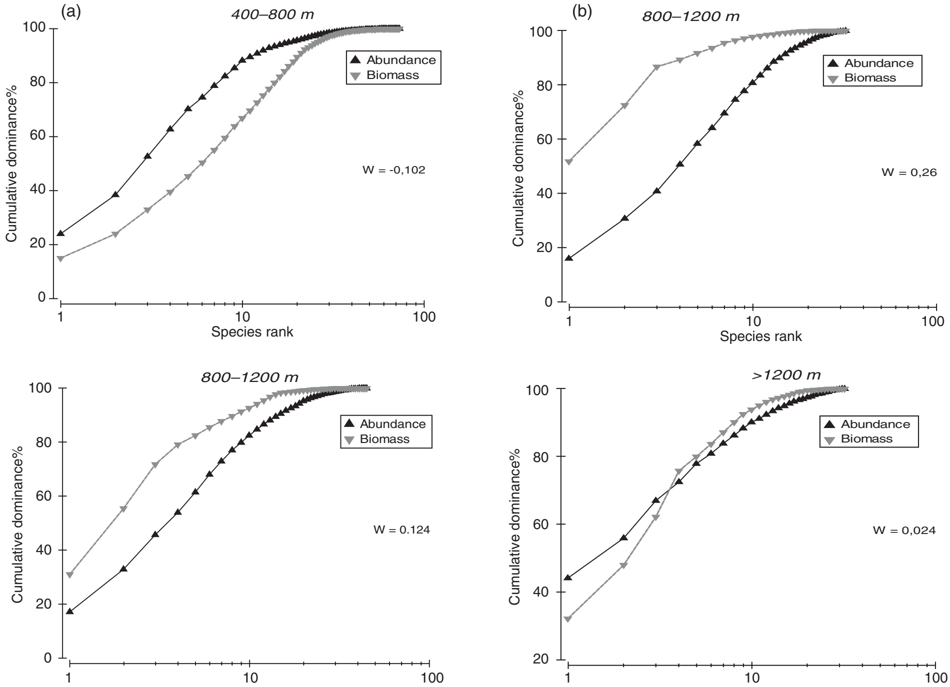

Figure 2. Abundance Biomass Comparison (ABC) plots for benthopelagic species (fishes, crustaceans and cephalopods) collected from upper to lower slope in the north-western Ionian Sea during DESEAS (a) and GAVIS (b) projects.

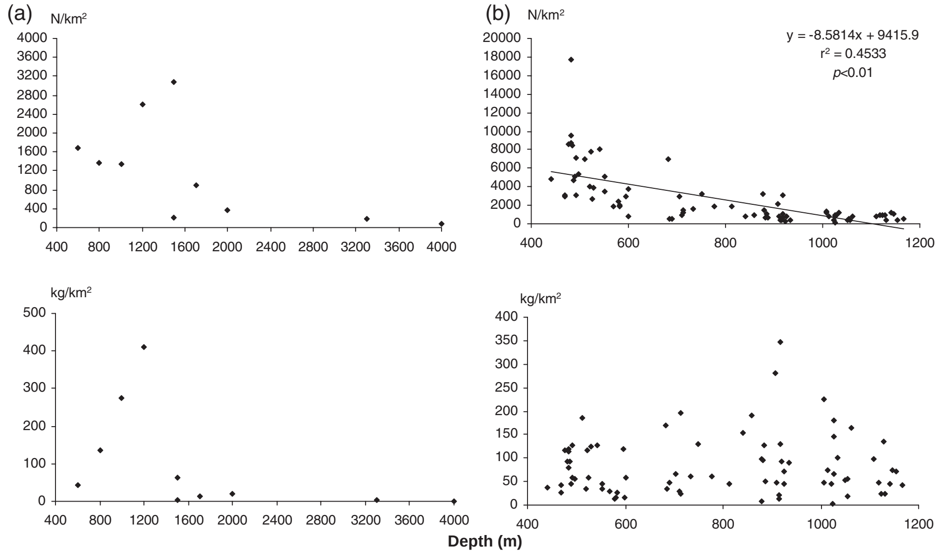

Figure 3. Relationship between density ($N{\cdot}km^{-2}$), biomass ($kg{\cdot}km^{-2}$) and depth for the benthopelagic species collected in the north-western Ionian Sea during (a) DESEAS (fish species) and (b) GAVIS (fishes, crustaceans and cephalopods) projects.

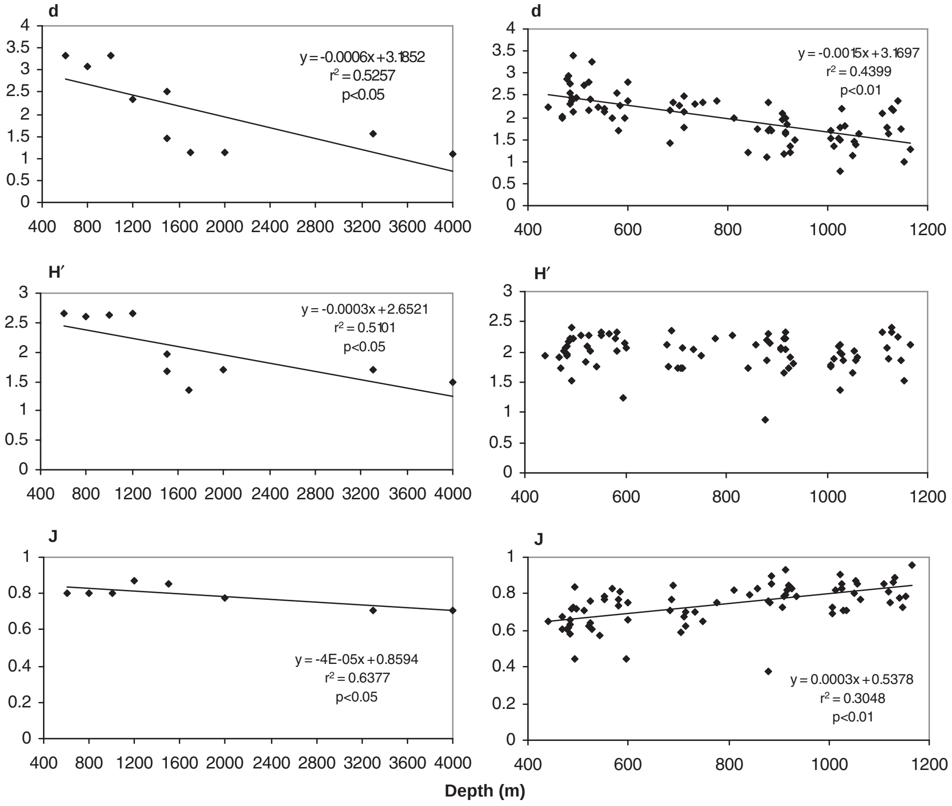

Figure 4. Relationship between species richness (d), diversity (H′), evenness (J′) and depth of benthopelagic species collected in the north-western Ionian Sea during (left) DESEAS (fish species) and (right) GAVIS (fishes, crustaceans and cephalopods) projects.

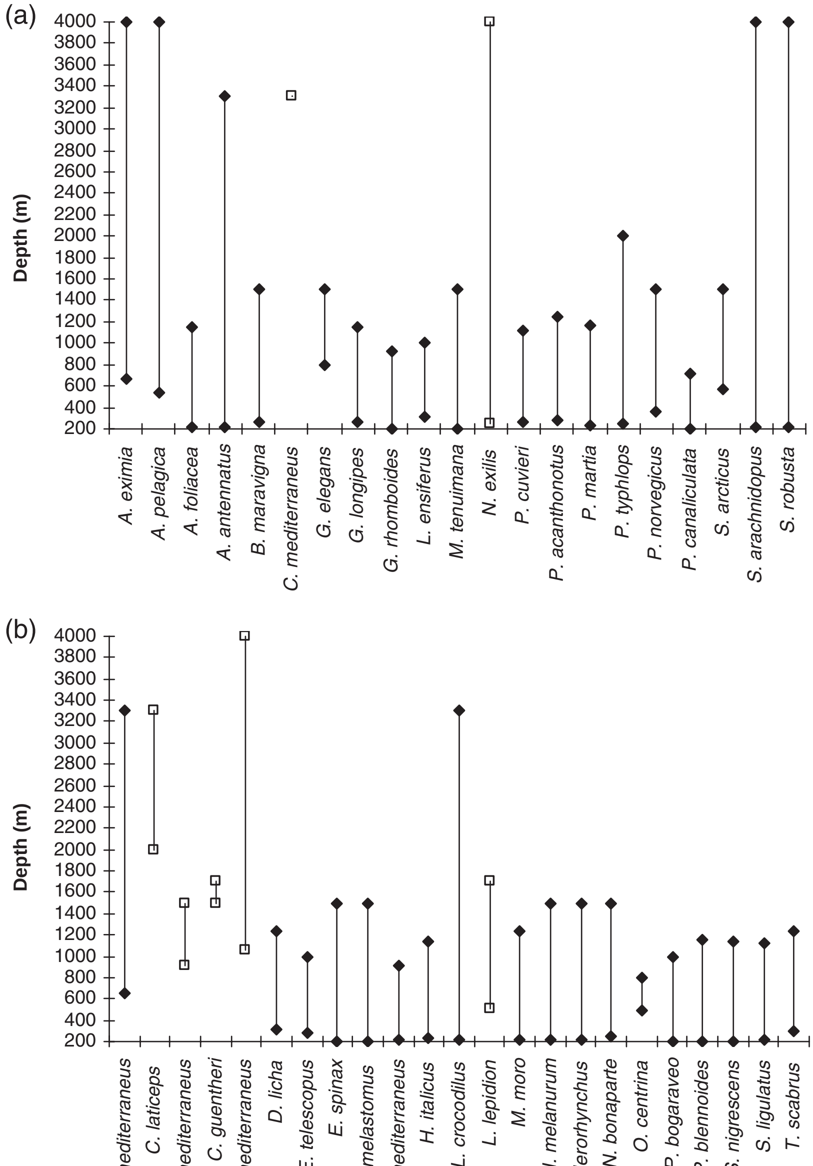

Figure 5. Depth records with indication of new findings (☐) of some deep-water crustaceans (a) and fishes (b) collected in the north-western Ionian Sea.

A. antennatus [42]. In particular, although highly variable abundance indices were shown in both shrimps in terms of density and biomass (Figure 7), a significant increase was only detected in *A. foliacea* ($R = 0.521$, $p < 0.05$ for density; $R = 0.606$, $p < 0.01$ for biomass), whereas the abundance changes observed for *A. antennatus* did not show any significant trend. The increase in both biomass and density of *A. foliacea* correlated significantly with the increase in temperature and salinity detected from 1995 to 2005 between 200 and 800 m in the studied area (biomass–salinity: $R = 0.587$, $p < 0.05$; biomass–temperature: $R = 0.627$, $p < 0.01$; density–salinity: $R = 0.503$, $p < 0.05$; density–temperature: $R = 0.558$, $p < 0.05$).

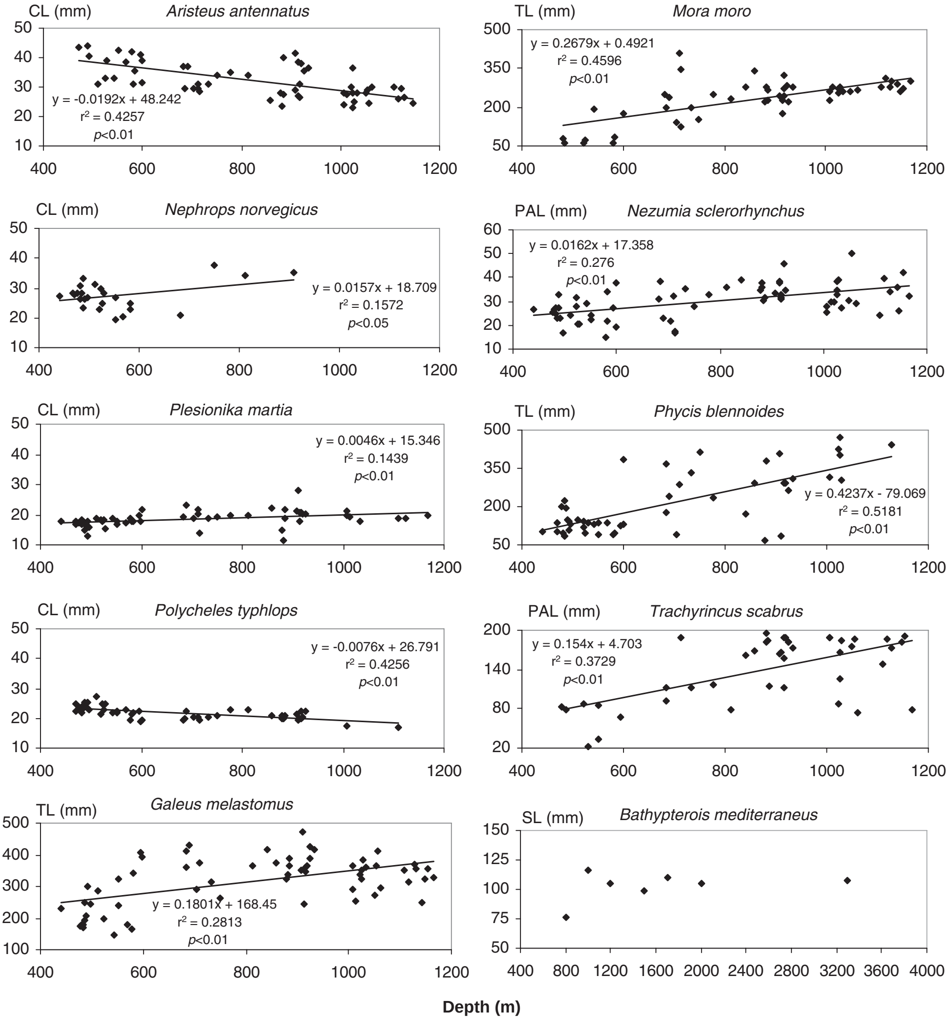

Figure 6. Relationship between size and depth in some deep-water benthopelagic species captured in the north-western Ionian Sea.

The length/frequency distributions of *A. foliacea* and *A. antennatus* also showed a different pattern (Figure 8). In fact, the sampled population mainly consisted of medium–small individuals in *A. foliacea*, whereas all the sizes were well represented in all investigated periods in *A. antennatus* length/frequency distributions.

During tagging experiments carried out in the Roccella Jonica canyon, some individuals of *A. antennatus* were caught at a depth of 198 m and after tagging were released. One month after tagging, one specimen was recaptured at a depth of 506 m. During this month, the tagged specimen covered at least 10 nautical miles, moving north-east and to greater depths. This first recapture gives interesting indications about the displacement of the shrimp both in vertical and horizontal space as well as on its growth rate [62,63].

Concerning the Santa Maria di Leuca coral habitat, density and biomass indices of the benthopelagic fauna showed greater values inside the coral habitat than outside (Figure 9) [64]. The sizes of the species analysed showed of larger individuals inside the coral habitat than outside (Figure 10).

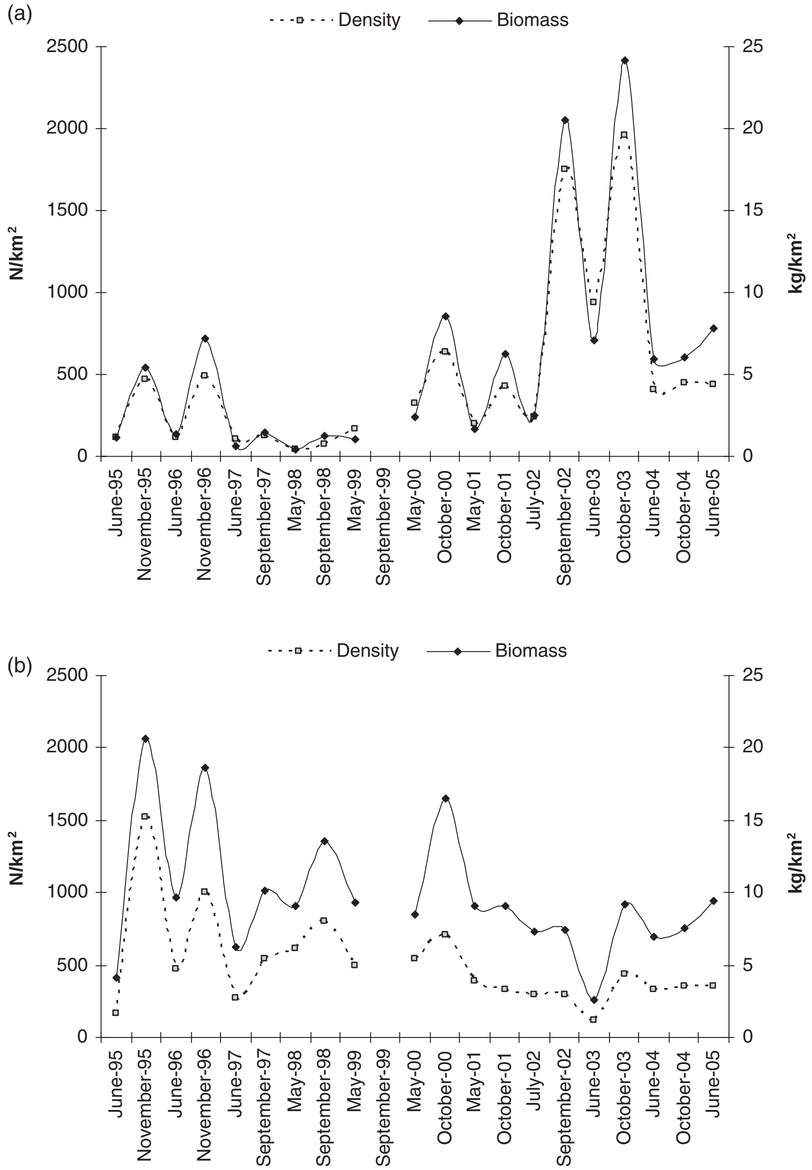

Figure 7. Fluctuations in the density (N·km^{-2}) and biomass (kg·km^{-2}) indices computed for *Aristaeomorpha foliacea* (a) and *Aristeus antennatus* (b) from 1995 to 2005 in the north-western Ionian Sea.

4. Discussion and conclusions

As observed in the North Atlantic [66,67] and in various areas of the Mediterranean Sea [8,23,24], including the Ionian Sea [12,15,26], depth is the main factor influencing the structure of the deep-water demersal assemblages.

The results reported in this study also demonstrate a tight link between the structure of benthopelagic fauna and depth. In fact, abundance and species richness decline with depth, as observed worldwide irrespective of the depth range examined [19,24,25,68,73,77]. Evenness increases making the diversity rather stable within ∼1200 m although both evenness and diversity decline with

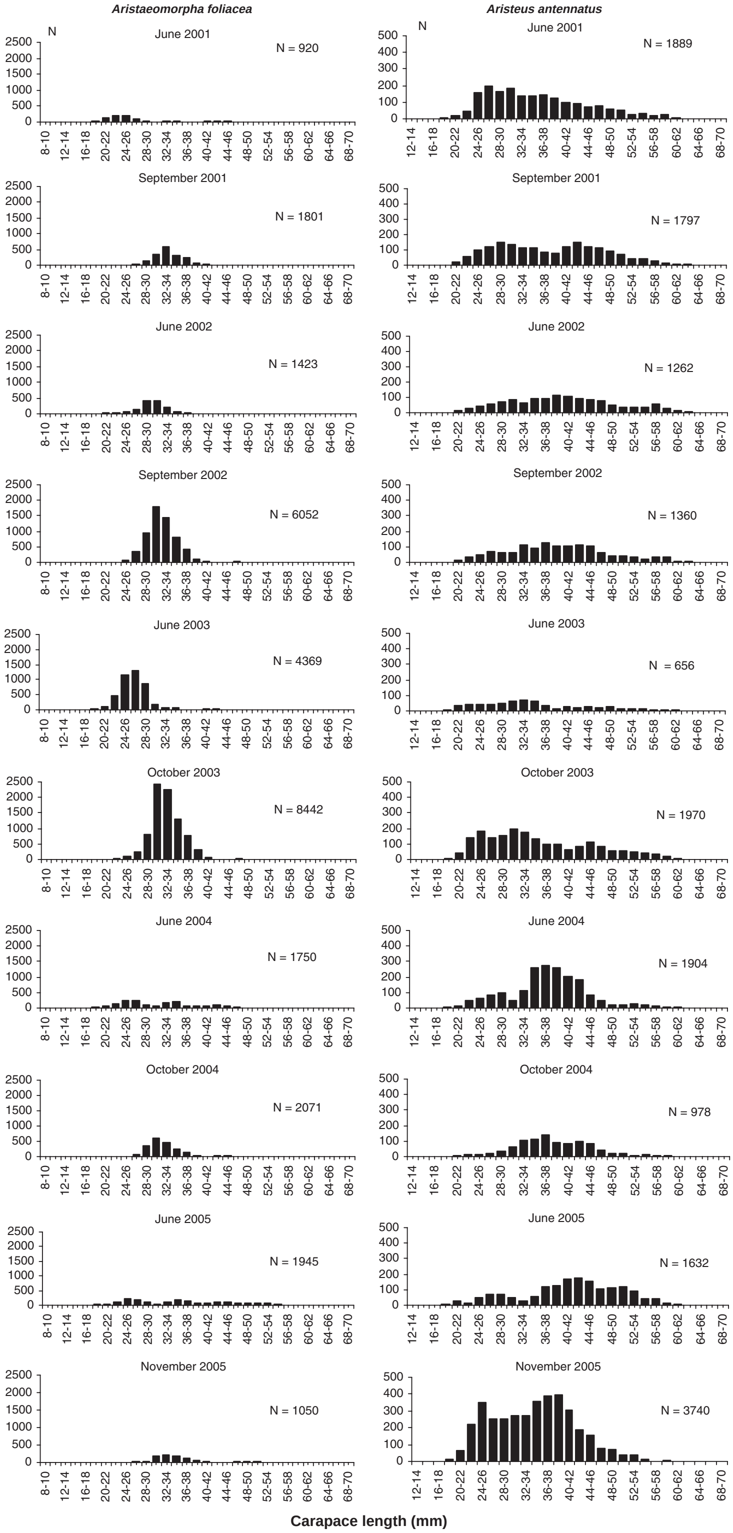

Figure 8. Length–frequency distribution of *Aristaeomorpha foliacea* and *Aristeus antennatus* sampled from 2001 to 2005 in the north-western Ionian Sea.

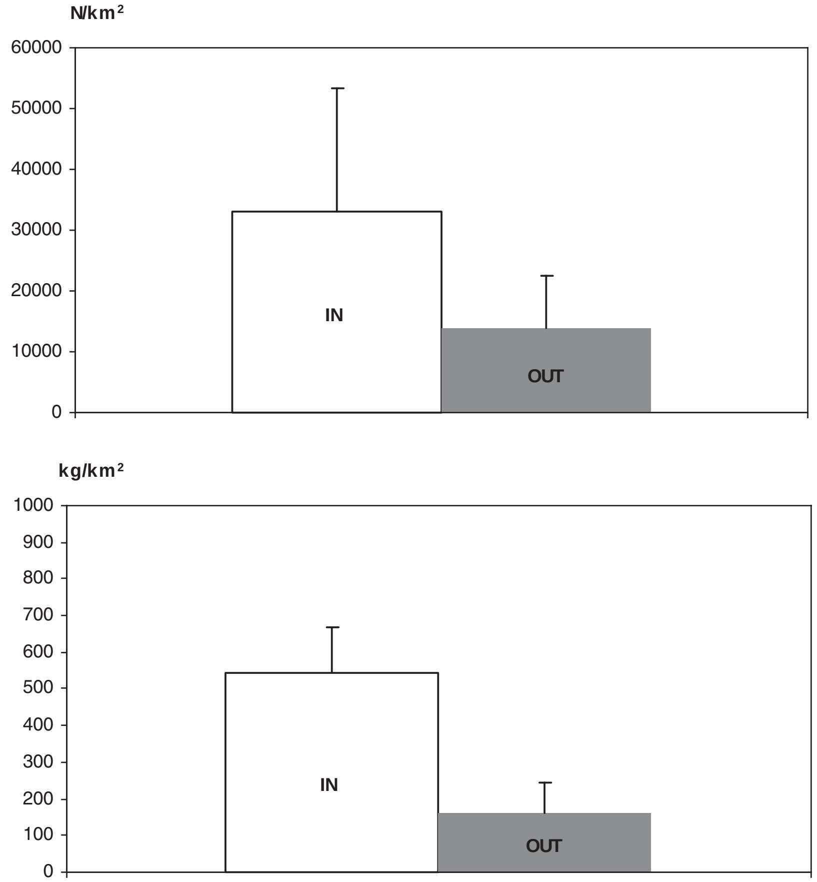

Figure 9. Average density and biomass indices, with standard deviation, computed for the benthopelagic fauna caught by trawl net, inside (IN) and outside (OUT) the Santa Maria di Leuca coral habitat.

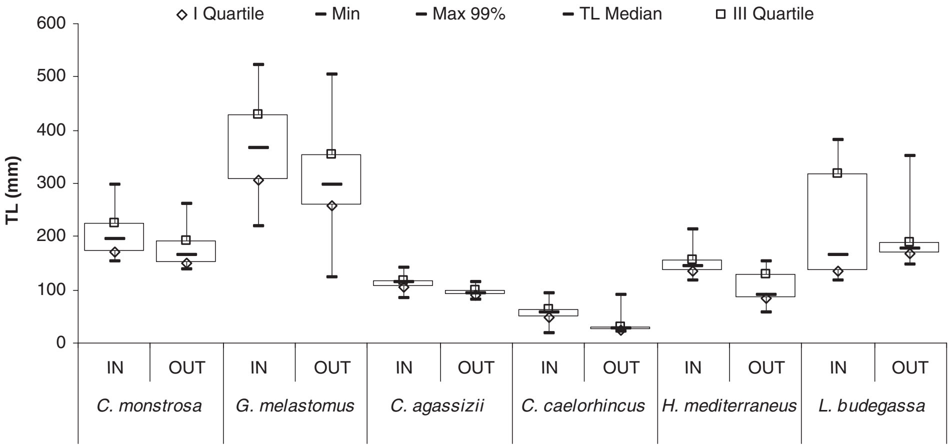

Figure 10. Box-plot of the sizes in *Chimaera monstrosa*, *Galeus melastomus*, *Chlorophthalmus agassizii*, *Coelorinchus caelorhincus*, *Hoplostethus mediterraneus* and *Lophius budegassa* collected inside (IN) and outside (OUT) the Santa Maria di Leuca coral habitat.

depth if a deeper vertical range is examined. Although not significant, the greatest biomass values were recorded on the upper–middle slope as a consequence of an increase in fish size rather than an increase in number.

The 400–800 m assemblage exhibited the greatest mean values of density and species richness with a higher abundance than biomass curve, indicating an assemblage characterised by a greater number of small and more abundant species. In the middle slope, between 800 and 1200 m, the biomass curve is more elevated than that of numerical abundance indicating a greater equitability in the assemblage. In the lower slope, the curve of abundance crosses that of biomass mostly probably because of the occurrence of both smaller and larger species of crustaceans and fishes.

The decrease in species number and the increase in evenness around 1000–1200 m is in agreement with observations carried out in the Cretan Sea on the whole demersal community [10] and in the other Mediterranean areas for deep-water fish assemblages [24,26]. According to deep-water investigations in the Atlantic and Mediterranean [23,24,27,69,70] the peak of biomass recorded on the middle slope is due to the presence of large-sized species, such as *G. melastomus*, *M. moro* and *T. scabrus*, that replace smaller species of both fish and crustaceans which dominate the upper slope species assemblage. This is a common pattern throughout the Mediterranean, although some geographic differences are due to energetic constraints and physical conditions [26,33]. The availability of trophic resources linked to the distribution of mesopelagic organisms has often been considered the main cause of a biomass peak in the middle slope [23,69,70]. Moreover, the biomass peak observed in the suprabenthos organisms between 800 and 1300 m in the western Mediterranean [71] can also explain the abundance of deep-water fishes which feed on these organisms [72–74].

As reported by Moranta et al. [27], the biomass peak is related to the species-specific bathymetric responses of the above-mentioned species distributed with the largest individuals in the middle slope. In fact, the species turnover also seems to reflect the depth-related trend of the dominant species which perform ontogenetic migration along the bathymetric gradient [18,75]. Stefanescu et al. [22] did not reveal any depth–size trend in *M. moro* because they investigated a depth range, between 1000 and 2250 m, deeper than where recruitment of this fish occurs. Also Morales-Nin et al. [76] and Moranta et al. [27] reported positive trends in *G. melastomus*, *P. blennoides* and macrourid fish, but not in *M. moro*. However, they collected this fish at depths >700 m. The positive relationship between size and depth detected in *P. martia* is in agreement with observations by Company and Sardà [77] in the western Mediterranean and Maiorano et al. [78] in the Ionian Sea. The smaller–deeper trend observed in *A. antennatus* and *P. typhlops* is due to the deeper distribution of juveniles and males which are smaller than females in both species [79–81].

Many studies on feeding habits in the lower slope fish species have indicated the presence of active predators such as *C. coelolepis* and *E. spinax* feeding on a wide range of benthic and free-swimming organisms, and species such as *B. mediterraneus* with reduced mobility and a microphagous filtering diet [37,82–84]. In addition, a degree of overlap between these two extreme trophic strategies seems to be due to other species, belonging to the Macrouridae, Moridae and Bythitidae families, which feed on food occurring within the benthic boundary and at the bottom interface [72,82,83,85–87].

It is well known that most deep-water species are slow-growing with a low reproductive capacity and are adapted to live in an ecosystem of low energy turnover. Thus, they are highly vulnerable to exploitation [37]. In relation to the importance of depths below 800–1000 m for the reproduction of many species, as well as for the juveniles of others such as *A. antennatus*, the exploitation of these bottoms would determine negative effects on shallower ecosystems, beyond the quick depletion of the several stocks [36].

Although the effects of fishing have been detected for the deep-water shrimp *A. foliacea* according to previous observations in the Ionian Sea [88], during the period 2000–2004 an uncommon increase in the abundance of this shrimp was recorded with both density and biomass found to be far greater than those of *A. antennatus* [42]. The inverted abundance of the two red shrimps during 2000–2004 seems to have been due to a temporary change in hydrographic conditions in the Ionian Sea. According to Ghidalia and Bourgois [89] and Bombace [35], such hydrographic conditions seem to favour *A. foliacea* but not *A. antennatus*, which seems to be more linked to colder and less saline waters. These results point out how the dynamics of the aquatic populations are influenced by the complexity of the ecosystem processes coupled with human activities [43].

In the Mediterranean, deep-water species are adapted to a general oligotrophic environment with local habitats of higher productivity and biodiversity hotspots. These deep-water habitats are also sensitive to human modification related to fishing, waste disposal and chemical pollution. The canyons represent a physical discontinuity over the continental slope which plays a role in the migrating processes of the fauna, favouring a coupling between bathyal and coastal waters due to both upwelling and cascading conditions [36,43]. Interactions between fauna and canyons determine differences in the distribution of the species and biomass between this type of habitat and surrounding areas on the continental slope. In addition, canyons can act as an ‘ecological refuge’ for many bathyal species. In fact, these habitats are unsuitable for trawling and represent a sheltered site for species during sensitive phases of their life cycle or for species well adapted to unstable environments.

The Santa Maria di Leuca coral bank represents a rare example of living *Lophelia–Madrepora*-bearing coral mounds and a biodiversity hotspot in the Mediterranean Sea, because more than 220 species have been recorded to date [90]. Data from trawling has revealed significant differences in the abundance of the fauna between coral and non-coral habitats [64]. The greater sizes shown in different species of fish inside the coral habitat indicate that it acts as a refuge area for these demersal species which are accidentally exploited outside. Considering the evidence of the negative impact of bottom trawling and, to a lesser extent, longlining, the Santa Maria di Leuca coral bank plays a role in the conservation of unique species and habitats as well as in providing benefit to adjacent fisheries through the spill-over effect of eggs, larvae, juveniles and adults [64]. Finally, the results summarised in this article point out the importance of the deep-sea investigations according to multidisciplinary approaches. Indeed, very little is still known about bathyal benthopelagic fauna and biodiversity, as well as on their relevant variations with respect to the different habitats and in relation to human intervention in the deep-sea both directly, through fishing and pollution, and indirectly by climate changes.

References

[1] C.C. Emig and P. Geistdoerfer, *The Mediterranean deep-sea fauna: Historical evolution, bathymetric variations and geographical changes*, Carnets de Géologie/Notebooks on Geology, Maintenon, Article 2004/01 (CG2004_A01_CCE-PG), 2004.

[2] L. Laubier and C. Emig, *La faune benthique profonde de Méditerranée*, Symposium Mediterranean Seas 2000, N.F.R. Della Croce, ed., 1993, pp. 397–428.

[3] F. Sardá, A. Calafat, M. Flexas, A. Tselepides, M. Canals, M. Espino, and A. Tursi, *An introduction to Mediterranean deep-sea biology*, in *Mediterranean deep-sea biology*, F. Sardá et al., eds., Sci. Mar. 68(Suppl. 3) (2004), pp. 7–38.

[4] J.S. Ryland, *European marine biology: Past, present and future*, Biol. Mar. Mediterr. 7(1) (2000), pp. 1–27.

[5] G. Relini, J. Bertrand, and A. Zamboni, *Synthesis of the knowledge on bottom fishery resources in central Mediterranean, Italy and Corsica*, Biol. Mar. Mediterr. 6(Suppl. 1) (1999), pp. 1–868.

[6] C. Stefanescu, B. Morales-Nin, and E. Massutí, *Fish assemblages on the slope in the Catalan Sea (western Mediterranean): Influence of a submarine canyon*, J. Mar. Biol. Ass. UK 74 (1994), pp. 499–512.

[7] E. Massutí, O. Reñones, A. Carbonell, and P. Oliver, *Demersal fish communities exploited on the continental shelf and slope off Maiorca (Balearic Islands, NW Mediterranean)*, Vie Milieu 46(1) (1996), pp. 4–55.

[8] N. Ungaro, G. Marano, and R. Marsan, *Demersal fish assemblage biodiversity as fishery resources exploitation*, Ital. J. Zool. 65(Suppl.) (1998), pp. 511–516.

[9] G. D’Onghia, A. Tursi, P. Maiorano, A. Matarrese, and M. Panza, *Demersal fish assemblages from the bathyal grounds of the north-western Ionian Sea*, Ital. J. Zool. 65(Suppl.) (1998), pp. 287–292.

[10] A. Kallianiotis, K. Sophronidis, P. Vidoris, and A. Tselepides, *Demersal fish and megafaunal assemblages on the Cretan continental shelf and slope (NE Mediterranean): Seasonal variation in species density, biomass and diversity*, Prog. Oceanog. 46 (2000), pp. 429–455.

[11] F. Biagi, P. Sartor, G.D. Ardizzone, P. Belcari, A. Belluscio, and F. Serena, *Analysis of demersal assemblages off the Tuscany and Latium coasts (north-western Mediterranean)*, Sci. Mar. 66(Suppl. 2) (2002), pp. 233–242.

[12] G. D'Onghia, F. Mastrototaro, A. Matarrese, C.-Y. Politou, and Ch. Mytilineou, *Biodiversity of the upper slope demersal community in the eastern Mediterranean: Preliminary comparison between two areas with and without trawl fishing*, J. Northw. Atl. Fish Sci. 31 (2003), pp. 263–273.

[13] M. Labropoulou and C. Papaconstantinou, *Community structure and diversity of demersal fish assemblages: The role of fishery*, Sci. Mar. 68(Suppl. 1) (2004), pp. 215–226.

[14] B. Mérigot, J.A. Bertrand, J.-C. Gaertner, J.-P. Durbec, N. Mazouni, and C. Manté, *The multi-component structuration of the species diversity of groundfish assemblages of the east coast of Corsica (Mediterranean Sea): Variation according to the bathymetric strata*, Fish. Res. 88 (2007), pp. 120–132.

[15] C.-Y. Politou, Ch. Mytilineou, G. D'Onghia, and J. Dokos, *Demersal faunal assemblages in the deep waters of the eastern Ionian Sea*, J. Nat. Hist. 42(5–8) (2008), pp. 661–672.

[16] P. Geistdoerfer and M. Rannou, *Poissons benthiques récoltés en Méditerranée occidentale par le N.O. Jean Charcot (campagne Polymède)*, Bull. Mus. Natn. Hist. Nat. Paris Series 3 25(19) (1972), pp. 101–110.

[17] C. Allué, J.A. Rucabado, D. Lloris, and R. Allué, *Contribucion al conocimiento de la ictiofauna abisal del Mediterráneo español*, Bull. Soc. Catal. Ictiol. Herpetol. 10 (1984), pp. 8–13.

[18] E. Macpherson and C.M. Duarte, *Bathymetric trends in demersal fish size: Is there a general relationship?* Mar. Ecol. Prog. Ser. 71 (1991), pp. 103–112.

[19] J.E. Cartes and F. Sardà, *Abundance and diversity of decapod crustaceans in the deep-Catalan Sea (western Medierranean)*, J. Nat. Hist. 26 (1992), pp. 1305–1323.

[20] J.E. Cartes and F. Sardà, *Zonation of deep-sea decapod fauna in the Catalan Sea (western Mediterranean)*, Mar. Ecol. Prog. Ser. 94 (1993), pp. 27–34.

[21] C. Stefanescu, D. Lloris, and J. Rucabado, *Deep-living demersal fishes in the Catalan Sea (western Mediterranean) below a depth of 1000 m*, J. Nat. His. 26 (1992), pp. 197–213.

[22] C. Stefanescu, J. Rucabado, and D. Lloris, *Depth-size trends in western Mediterranean demersal deep-sea fishes*, Mar. Ecol. Prog. Ser. 81 (1992), pp. 205–213.

[23] C. Stefanescu, D. Lloris, and J. Rucabado, *Deep-sea fish assemblages in the Catalan Sea (western Mediterranean) below a depth of 1000 m*, Deep-Sea Res. 40(4) (1993), pp. 695–707.

[24] J. Moranta, C. Stefanescu, E. Massutí, B. Morales-Nin, and D. Lloris, *Fish community structure and depth-related trends on the continental slope of the Balearic Islands (Algerian basin, western Mediterranean)*, Mar. Ecol. Prog. Ser. 171 (1998), pp. 247–259.

[25] J.B. Company, P. Maiorano, A. Tselespides, C.-Y. Politou, W. Plaity, G. Rotllant, and F. Sardá, *Deep-sea decapod crustaceans in the western and central Mediterranean Sea: Preliminary aspects of species distribution, biomass and population structure*, Sci. Mar. 68(Suppl. 3) (2004), pp. 73–86.

[26] G. D'Onghia, C.-Y. Politou, A. Bozzano, D. Lloris, G. Rotlant, L. Sion, and F. Mastrototaro, *Deep-water fish assemblages in the Mediterranean Sea*, Sci. Mar. 68(Suppl. 3) (2004), pp. 87–99.

[27] J. Moranta, M. Palmer, E. Massutí, C. Stefanescu, and B. Morales-Nin, *Body fish size tendencies within and among species in the deep-sea of the western Mediterranean*, Sci. Mar. 68(Suppl. 3) (2004), pp. 141–152.

[28] D. Golani, *On deep-water sharks caught off the Mediterranean coast of Israel*, Israel J. Zool. 34 (1986/87), pp. 23–31.

[29] W. Klausewitz, *Deep-sea and deep water fish of the eastern Mediterranean, collected during the METEOR-Expedition 1987*, Senckenb Marit. 20(5/6) (1989), pp. 251–263.

[30] G. Albertelli, P.M. Arnaud, N. Della Croce, N. Drago, and A. Eleftheriou, *The deep Mediterranean macrofauna caught by traps and its trophic significance*, C.R. Acad. Sci. Paris 315 (Série III) (1992), pp. 139–144.

[31] B.S. Galil and M. Goren, *The deep sea Levantine fauna – New records and rare occurrences*, Senckenb. Marit. 25 (1994) pp. 41–52.

[32] M. Goren and B.S. Galil, *New records of deep-sea fishes from the Levant Basin and a note on the deep-sea fishes of the Mediterranean*, Israel J. Zool. 43 (1997), pp. 197–203.

[33] G. D'Onghia, D. Lloris, C.-Y. Politou, L. Sion, and J. Dokos, *New records of deep-water teleost fishes in the Balearic Sea and Ionian Sea (Mediterranean Sea)*, Sci. Mar. 68(Suppl. 3) (2004), pp. 171–183.

[34] L. Sion, A. Bozzano, G. D'Onghia, F. Capezzuto, and M. Panza, *Chondrichtyes species in deep waters of the Mediterranean Sea*, Sci. Mar. 68(Suppl. 3) (2004), pp. 153–162.

[35] G. Bombace, *Considerazioni sulla distribuzione delle popolazioni di livello batiale con particolare riferimento a quelle bentonectoniche*, Pubbl. Staz. Zool. Napoli 39(Suppl.) (1975), pp. 7–21.

[36] J.E. Cartes, F. Maynou, F. Sardà, J.B. Company, D. Lloris, and S. Tudela, *The Mediterranean deep-sea ecosystems: An overview of their diversity, structure, functioning and anthropogenic impacts*, in *The Mediterranean Deep-Sea Ecosystems: An Overview of their Diversity, Structure, Functioning and Anthropogenic Impacts, with a Proposal for Conservation*, IUCN, Malaga and WWF, Rome, 2004, pp. 9–38.

[37] N.R. Merrett and R.L. Haedrich, *Deep-Sea Demersal Fish and Fisheries*, Chapman & Hall, London, 1997.

[38] J.P. Béthoux, B. Gentili, J. Raunet, and D. Tailliez, *Warming trend in the western Mediterranean deep water*, Nature 347 (1990), pp. 600–662.

[39] J.F. Caddy, R. Refk, and T. Do-Chi, *Productivity estimates for the Mediterranean: Evidence of accelerating ecological change*, Ocean Coast. Manage. 26(1) (1995), pp. 1–18.

[40] R. Danovaro, A. Dell'Anno, M. Fabiano, A. Pusceddu, and A. Tselepides, *Deep-sea ecosystem response to climate changes: The eastern Mediterranean case study*, Trends Ecol. Evol. 16(9) (2001), pp. 505–510.

[41] R. Danovaro, A. Dell'Anno, and A. Pusceddu, *Biodiversity response to climate change in a warm deep sea*, Ecol. Lett. 7 (2004), pp. 821–828.

[42] R. Carlucci, G. D'Onghia, P. Maiorano, L. Sion, F. Capezzuto, A. Matarrese, and A. Tursi, *Abundance and size fluctuations in the deep-water shrimps* Aristaeomorpha foliacea *(Risso, 1827) and* Aristeus antennatus *(Risso, 1819) in the north-western Ionian Sea (Mediterranean Sea)*, CIESM 38 (2007), p. 445.

[43] J.B. Company, P. Puig, F. Sardà, A. Palanques, M. Latasa, and R. Scharek, *Climate influence on deep sea populations*, Plos ONE 3(1) (2008), e1431, pp. 1–8.

[44] B. Klein, W. Roether, B. Manca, D. Bregant, V. Beitzel, V. Kovacevic, and A. Luchetta, *The large deep transient in the eastern Mediterranean*, Deep-Sea Res. I 46 (1999), pp. 371–414.

[45] P. Malanotte-Rizzoli, B.B. Manca, M. Ribera d'Alcala, A.Theocharis, S. Brenner, G. Budillon, and E. Ozsoy, *The eastern Mediterranean in the 80s and in the 90s: The big transition in the intermediate and deep circulations*, Dyn. Atmos. Oceans 29(2–4) (1999), pp. 365–395.

[46] S. Rossi and G. Gabbianelli, *Geomorfologia del Golfo di Taranto*, Boll. Soc. Geol. It. 97 (1978), pp. 423–437.

[47] A. Tursi, F. Mastrototaro, A. Matarrese, P. Maiorano, and G. D'Onghia, *Biodiversity of the white coral reefs in the Ionian Sea (central Mediterranean)*, Chem. Ecol. 20(Suppl. 1) (2004), pp. 107–116.

[48] M. Taviani, A. Remia, C. Corselli, A. Freiwald, E. Malinverno, F. Mastrototaro, A. Savini, and A. Tursi, *First geo-marine survey of living cold-water* Lophelia *reefs in the Ionian Sea (Mediterranean basin)*, Facies 50 (2005), pp. 409–417.

[49] G. Relini, *Valutazione delle risorse demersali*, Biol. Mar. Medit. 5 (1998), pp. 3–19.

[50] A. Tursi, A. Matarrese, G. D'Onghia, M. Panza, P. Maiorano, M. Basanisi, F. Perri, C. Marano, and F. Casamassima, *Density, abundance and structure of population of red shrimps*, Aristeus antennatus *and* Aristaeomorpha foliacea, *in the Ionian Sea (Southern Italy)*, EEC Research Programme MED/92/015 Fin. Rep., 1996.

[51] J.A. Bertrand, L. Gil de Sola, C. Papaconstantinou, G. Relini, and A. Souplet, *An international bottom trawl survey in the Mediterranean: The MEDITS programme*, IFREMER Actes de Colloques 26 (2000), pp. 76–93.

[52] C. Corselli, P. Favali, M.A. Rosso, G. Spezie, M. Taviani, A. Savini, G. Etiope, A. Tursi, F. Mastrototaro, and A. Remia, *Aplabes Consortium*. *The Santa Maria di Leuca* Lophelia *reefs of the Mediterranean sea*: *A research in progress*, EGU General Assembly, Vienna, 2006, p. 05714.

[53] G. D'Onghia, P. Maiorano, F. Capezzuto, R. Carlucci, D. Battista, A. Giove, L. Sion, and A. Tursi, *Further evidences of deep-sea recruitment of* Aristeus antennatus *(Crustacea: Decapoda) and its role in the population renewal on the exploited bottoms of the Mediterranean*, Fish. Res. 95(2-3) (2009), pp. 236–245.

[54] L. Fiorentini, G. Cosimi, A. Sala, and V. Palombo, *Caratteristiche e prestazioni delle attrezzature a strascico impiegate per la Valutazione delle Risorse Demersali in Italia*, Biol. Mar. Mediterr. 1 (1994), pp. 115–134.

[55] L. Fiorentini, P.-Y. Dremière, I. Leonori, A. Sala, and V. Palombo, *Efficiency of the bottom trawl used for the Mediterranean International Trawl Survey (MEDITS)*, Aquat. Living Resour. 12(3) (1999), pp. 187–205.

[56] D. Pauly, *Some simple methods for the assessment of tropical fish stocks*, FAO Fish Tech. Pap. 234 (1983), pp. 1–52.

[57] P.J.D. Lambshead, H.M. Platt, and K.M. Shaw, *The detection of differences among assemblages of benthic species based on an assessment of dominance and diversity*, J. Nat. Hist. 17 (1983) pp. 859–874.

[58] R.M. Warwick, A *new method for detecting pollution effects on marine macrobenthic communities*, Mar. Biol. 92 (1986), pp. 557–562.

[59] A.E. Magurran, *Ecological Diversity and its Measurement*, Croom Helm, London, 1991.

[60] CIESM, *Climate warming and related changes in Mediterranean marine biota*, N° 35 in *CIESM Workshop Monographs*, F. Briand, ed., CIESM, Monaco, 2008.

[61] A. Matarrese, G. D'Onghia, M. De Florio, M. Panza, and G. Costantino, *Recenti acquisizioni sulla distribuzione batimetrica di* Aristaeomorpha foliacea *ed* Aristeus antennatus *(Crustacea, Decapoda) nel Mar Jonio*, Biol. Mar. Mediterr. 2(2) (1995), pp. 299–300.

[62] M. Relini, P. Maiorano, G. D'Onghia, L. Orsi Relini, A. Tursi, and M. Panza, *A pilot experiment of tagging the deep shrimp* Aristeus antennatus *(Risso, 1816)*, Sci. Mar. 64(3) (2000), pp. 357–361.

[63] M. Relini, P. Maiorano, G. D'Onghia, L. Orsi Relini, A. Tursi, and M. Panza, *Recapture of tagged deep-sea shrimp* Aristeus antennatus *(Risso, 1816) in the Mediterranean Sea*, Rapp. Comm. Int. Mer. Méditerr. 37 (2004), p. 424.

[64] G. D'Onghia, P. Maiorano, L. Sion, A. Giove, F. Capezzuto, R. Carlucci, and A.Tursi, *Effects of deep-water coral banks on the abundance and size structure of the megafauna in the Mediterranean sea*, Deep-Sea Res. II 57 (2009), pp. 397–411.

[65] F. Sardà, G. D'Onghia, C.-Y. Politou, J.B. Company, P. Maiorano, and K. Kapiris, *Deep-sea distribution, biological and ecological aspects of* Aristeus antennatus *in the western and central Mediterranea*n *Sea*, Sci. Mar. 68(3) (2004), pp. 117–127.

[66] P.V.R. Snelgrove and R.L. Haedrich, *Structure of the deep demersal fish fauna off Newfoundland*, Mar. Ecol. Prog. Ser. 27 (1985), pp. 99–107.

[67] B. Hecker, *Variation in megafaunal assemblages on the continental margin south of New England*, Deep-Sea Res. 37(1) (1990), pp. 37–57.

[68] R.S. Lampitt, D.S.M. Billet, and A.L. Rice, *Biomass of the invertebrate megabenthos from 500 to 4100 m in the northeast Atlantic Ocean*, Mar. Biol. 93 (1986), pp. 69–81.

[69] N.B. Marshall and N.R. Merrett, *The existence of benthopelagic fauna in the deep-sea*, Deep-Sea Res. 24(Suppl.) (1977), pp. 483–497.

[70] J.D.M. Gordon and J.A.R. Duncan, *The ecology of the deep-sea benthic and benthopelagic fish on the slopes of the Rockall Trough, northeastern Atlantic*, Prog. Oceanogr. 15 (1985), pp. 37–69.

[71] J.E. Cartes, F. Maynou, B. Morales-Nin, E. Massutí, and J. Moranta, *Trophic structure of a bathyal benthopelagic boundary layer community south of the Balearic Islands (southwestern Mediterranean)*, Mar. Ecol. Prog. Ser. 215 (2001), pp. 23–35.

[72] E. Macpherson, *Ecological overlap between Macrourids in the western Mediterranean Sea*, Mar. Biol. 53 (1979), pp. 149–159.

[73] E. Macpherson, *Resource partitioning in a Mediterranean demersal fish community*, Mar. Ecol. Prog. Ser. 4 (1981), pp. 183–193.

[74] M. Carrassón, J. Matallanas, and M. Casadevall, *Feeding strategies of deep-water morids on the western Mediterranean slope*, Deep-Sea Res. 44(9–10) (1997), pp. 1685–1699.

[75] G. Replant, J. Moranta, E. Massutí, F. Sardà, and B. Morales-Nin, *Reproductive biology of three Gadiform fish species through the Mediterranean deep-sea range (147–1850 m)*, Sci. Mar. 66(2) (2002), pp. 157–166.

[76] B. Morales-Nin, F. Maynou, F. Sardà, J. Cartes, J. Moranta, E. Massutí, J. Company, G. Rotllant, A. Bozzano, and C. Stefanescu, *Size influence in zonation patterns in fishes and crustaceans from deep-water communities of the western Mediterranean*, J. Northwest. Atl. Fish. Soc. 31 (2003), pp. 413–430.

[77] J.B. Company and F. Sardà, *Reproductive patterns and population characteristics in five deep-water pandalid shrimps in the western Mediterranean along a depth gradient (150–1100 m)*, Mar. Ecol. Prog. Ser. 148 (1997), pp. 49–58.

[78] P. Maiorano, G. D'Onghia, F. Capezzuto, and L. Sion, *Life-history traits of* Plesionika martia *(Decapoda: Caridea) from the eastern–central Mediterranean Sea*, Mar. Biol. 141 (2002), pp. 527–539.

[79] P. Abelló and J.E. Cartes, *Population characteristics of the deep-sea lobsters* Polycheles typhlops *and* Stereomastis sculpta *(Decapoda: Polychelidae) in a bathyal mud community of the Mediterranean Sea*, Mar. Biol. 114 (1992), pp. 109–117.

[80] F. Sardà and J.E. Cartes, *Morphological features and ecological aspects of early juveniles specimens of the aristeid shrimp* Aristeus antennatus *(Risso, 1816)*, Mar. Freshwater Res. 48 (1997), pp. 73–77.

[81] P. Maiorano, M. Pastore, G. D'Onghia, and F. Latorre, *Note on the population structure and reproduction of* Polycheles typhlops *(Heller, 1862) (Decapoda: Polychelidae) on the upper slope of the Ionian Sea*, J. Nat. Hist. 32 (1998), pp. 1609–1618.

[82] M. Carrassón and J. Matallanas, *Preliminary data about the feeding habits of some deep-sea Mediterranean fishes*, J. Fish. Biol. 36 (1990), pp. 461–463.

[83] M.L. Mahaut, P. Geistdorfer, and M. Sibuet, *Trophic strategies in carnivorous fishes: Their significance in energy transfer in the deep-sea benthic ecosystem (Meriadzeck Terrace–Bay of Biscay)*, Prog. Oceanogr. 24 (1990), pp. 223–237.

[84] M. Carrassón, C. Stefanescu, and J.E. Cartes, *Diets and bathymetric distributions of two bathyal sharks of the Catalan deep sea (western Mediterranean)*, Mar. Ecol. Prog. Ser. 82 (1992), pp. 21–30.

[85] J. Mauchline and J.D.M. Gordon, *Diets and bathymetric distributions of the macrourid fish of the Rockall Trough, northeastern Atlantic Ocean*, Mar. Biol. 81 (1984), pp. 107–121.

[86] J. Mauchline and J.D.M. Gordon, *Feeding and bathymetric distribution of the gadoid and morid fish of the Rockall Trough*, J. Mar. Biol. Ass. UK 64 (1984), pp. 657–665.

[87] M. Carrassón and J. Matallanas, *Diets of deep-sea macrourid fishes in the western Mediterranean*, Mar. Ecol. Prog. Ser. 234 (2002), pp. 215–228.

[88] A. Matarrese, G. D'Onghia, A. Tursi, and P. Maiorano, *Vulnerabilità e resilienza di* Aristaeomorpha foliacea *(Risso, 1827) e* Aristeus antennatus *(Risso, 1816) (Crostacei, Decapodi) nel Mar Ionio*, S It E Atti 18 (1997), pp. 535–538.

[89] W. Ghidalia and F. Bourgois, *Influence de la témperature et de l'éclairement sur la distribution des crevettes des moyennes et grandes profondeurs*, Stud. Rev. Gentile. Fish. Count. Medit. FAO 16 (1961), pp. 1–53.

[90] F. Mastrototaro, G. D'Onghia, G. Corriero, A. Matarrese, P. Maiorano, P. Panetta, M. Gherardi, C. Longo, A. Rosso, F. Sciuto, R. Sanfilippo, C. Gravili, F. Boero, M. Taviani, and A. Tursi, *Biodiversity of the white coral bank off Cape Santa Maria di Leuca (Mediterranean Sea): An update*, Deep-Sea Res. II 57 (2009), pp. 412–430.