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Research Article

Commercial and non-target species of deep-water trawled muddy habitats on the Maltese continental shelf.

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Summary. *Prior to joining the European Union, Malta operated a 25nm Exclusive Fishing Zone that was retained as a Fisheries Conservation Zone (FCZ) following EU membership. The present study was conducted in this FCZ as part of the ongoing MEDITS trawl survey programme. Otter trawl samples were collected from muddy bottoms at depths of 100-300m. The catch from each haul was sorted into commercial and non-commercial components, and fauna were identified and counted. Samples for analyses of infauna and sediment characteristics were collected using a 0.0625m² capacity box-corer. Macrofaunal abundance data for the stations were analysed using ordination techniques (nMDS) and relationships between environmental variables and faunal assemblages were explored by superimposing individual variables on the two-dimensional nMDS plots. The analyses clearly separated the commercial species into two distinct groups of assemblages that seemed to be defined principally by depth: those from inshore and south-eastern stations (depth range 100-250m) and those from north-western stations (depth range 250-300m). The non-commercial species showed a similar pattern with assemblages from inshore stations grouping together; however, the offshore stations had a greater variability in non-target species composition, especially for infauna. For the offshore stations, geographical position seemed to be important since stations off the north-western coast of the Maltese islands grouped separately from those off south-eastern Malta.*

Keywords: *Fisheries Conservation Zone, trawling, fisheries, MEDITS, benthos, macrofauna, infauna, muddy bottoms, community structure.*

Introduction

Prior to joining the European Union, Malta managed an Exclusive Fishing Zone that extends to 25 nautical miles from the baseline of the Maltese Islands (Fig 1). Post-EU membership, this zone was retained as a Fisheries Management Zone (FMZ). The Maltese FMZ, which covers an area of 23,600 km^2, has a unique stock of demersal resources that are associated with certain physical and hydrographic features. For shallow shelf resources (<200 m) within the FMZ, adult populations are believed to be isolated to some degree from adjacent populations and there is limited exchange of adult individuals (Anonymous 2001; Camilleri, 2003). Therefore, the shelf seas around Malta can be regarded as an independent management unit for demersal resources. Knowledge of the demersal fisheries resources within this area is still poor although data are now being accumulated through Maltese participation in the Mediterranean International Trawl Survey (MEDITS; since 2000) and in the FAO programme MedSudMed. The MEDITS programme, in which all the Mediterranean European Union Member States participate, was designed to characterize the bottom fisheries resources in the Mediterranean by contributing annual data on population distribution (relative abundance) and demographic structure (length distributions, maturity stages, etc.) of the resource.

In recent years, there has been an increasing interest by fisheries scientists in ecosystem-based fisheries management, where fish stocks are no longer considered in isolation but as one component of an integrated ecosystem that includes the water column and the seabed (Link, 2002; Pitkitch *et al.*, 2004). Considered as such, management of a fish stock becomes an exercise in management of the ecosystem in such a way as to allow long-term harvesting of the resource without either causing collapse of the population to below sustainable levels, or harm to the other components of the system on which this resource depends (Gislason *et al.*, 2000; Link, 2002). In turn, such ecosystem management requires a good knowledge of the components of the system and how they interact together and against a change background of environmental conditions. Additionally, ecosystems and their biota are often vulnerable to anthropogenic activities such as demersal towed gears, which lead to changes in the benthic environment. Bottom trawling can lead to large-scale ecological effects that include physical disruption of the seabed, degradation of associated communities, over-fishing of demersal resources, changes in the structure and functioning of marine ecosystems as a result of the depletion of populations, and energy subsidies through large amounts of fisheries by-catch and the associated discards (Hall, 1999; Kaiser & De Groot, 2000).

National and international initiatives, including the establishment of no-fishing or restricted-fishing zones, such as the Malta FMZ, and other types of marine protected areas, increase the need to quantify the benthic environment within such areas. In this context, knowledge of the commercial demersal assemblages, the benthic assemblages, the associated benthic habitats, and of their respective interactions, is essential.

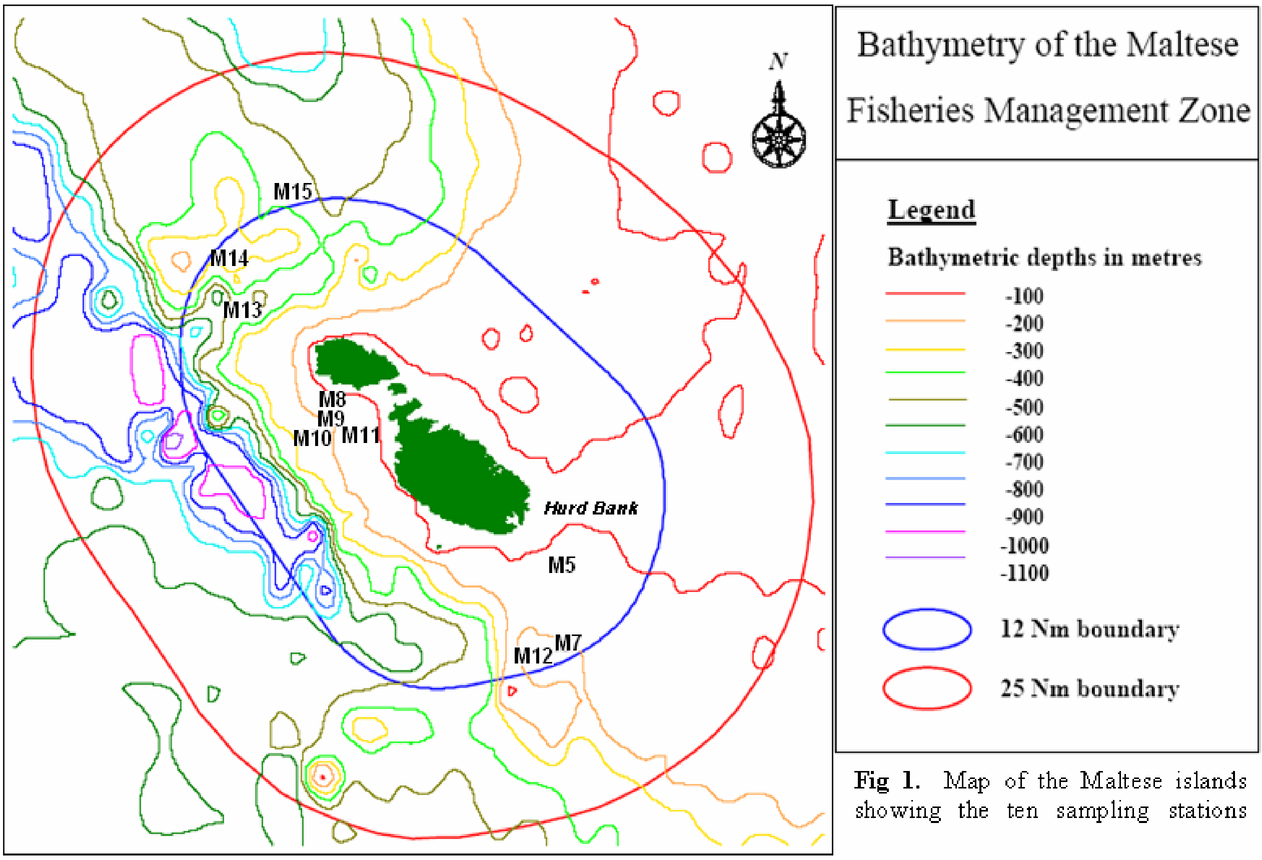

Fig 1. Map of the Maltese islands showing the ten sampling stations

At present, there is little information on the distribution of biological assemblages in relation to environmental parameters within the Maltese FMZ even if such information is essential for the management of living resources with this management unit. This paper aims to quantify the biota associated with the deep-water muddy bottoms (100 - 400m) of the Maltese islands and to investigate the spatial distribution of the biotic assemblages that these ecosystems support.

Sampling methodology

The present study was conducted in the Maltese 25 Nm FMZ as part of the ongoing MEDITS trawl survey programme. One otter trawl sample per station was collected in summer 2004 from stations located at different depths between 100m and 300m on muddy bottoms (Fig. 1). Sampling was undertaken on board the RV *Sant` Anna*. Each trawl haul lasted for ca. 45 minutes, depending on the depth and substratum type, and trawl speed was c. 3 knots; a semipelagic experimental trawl net (IFREMER GOC 73: width 22m; height of vertical opening, 2m; length, 40m; stretched mesh size at cod-end, 20mm) was used (Fiorentini *et al.*, 1999). The entire faunal component from each haul was sorted into commercial and non-target species, after which the fauna were identified and counted.

Three replicate samples for infauna and sediment analyses were collected using a 0.0625m² box-corer (Khalsico). Sediment granulometry and organic carbon were determined according to the procedures described by Buchanan (1984).

Statistical analyses

The macrofaunal abundance data for each station were analysed using ordination techniques. A similarity matrix was constructed from the fourth-root transformed abundance data using the Bray-Curtis similarity measure; non-metric multidimensional scaling (nMDS) ordination was then applied. The SIMPER program was used to determine which species contributed most to the similarity within each grouping of stations identified *a posteriori* (Clarke & Warwick, 1994a).

Relationships between measured abiotic characteristics (depth and sediment characteristics; see Table 3) and faunal assemblages were determined using the BIOENV procedure (Clarke & Ainsworth, 1993). and by superimposing scaled individual variables onto the sample locations on the two-dimensional nMDS ordination plots (Field *et al.*, 1982; Clarke & Warwick, 1994a). All the analyses were undertaken using the PRIMER 5.22 statistical software package (Clarke & Warwick, 1994b).

Results

Examination of the nMDS ordination plot revealed that the commercial species were separated into two distinct groups of stations: the inshore + south-eastern stations and the north-western deeper stations (Fig. 2a). The inshore and south-eastern sites were dominated by *Trachurus trachurus* (Atlantic Horse Mackerel), *Illex coindetti* (Broadtail Squid) and *Mullus barbatus* (Red Mullet), while the north-western stations were dominated by typically deeper water species such as *Aristeomorpha foliacea* (Giant Red Shrimp), *Nephrops norvegicus* (Norway Lobster) and *Galeus melastomus* (Blackmouth Catshark; Table 1). From the superimposition of the environmental variables on the two dimensional nMDS ordination plots, depth appeared to correlate best with the two identified biological groupings; in general, the depth of the inshore and south-eastern stations ranged from 100–250 m while for the north-western stations it ranged from 200–350 m. The non-target species showed a similar pattern with respect to the inshore stations (Fig. 2b), but there was a greater variability for the offshore stations (Table 2). There was also a strong correlation of the offshore stations with geographical position: stations off the north-western coast were grouped together, as were those off south-eastern Malta.

The dominant non-target species in the areas studied (Table 2.) where the crinoid *Leptometra phalangium*, juveniles of *Illex coindetti* and of *Parapanaeus longirostris*, and other natantian decapods (e.g. *Plesionika heterocarpus*). The infauna had the greatest spatial variation (Fig. 2c) but nonetheless, there is evidence of a depth gradient in infaunal assemblage composition. Stations M13 and M15 had no infauna and were excluded from the plots.

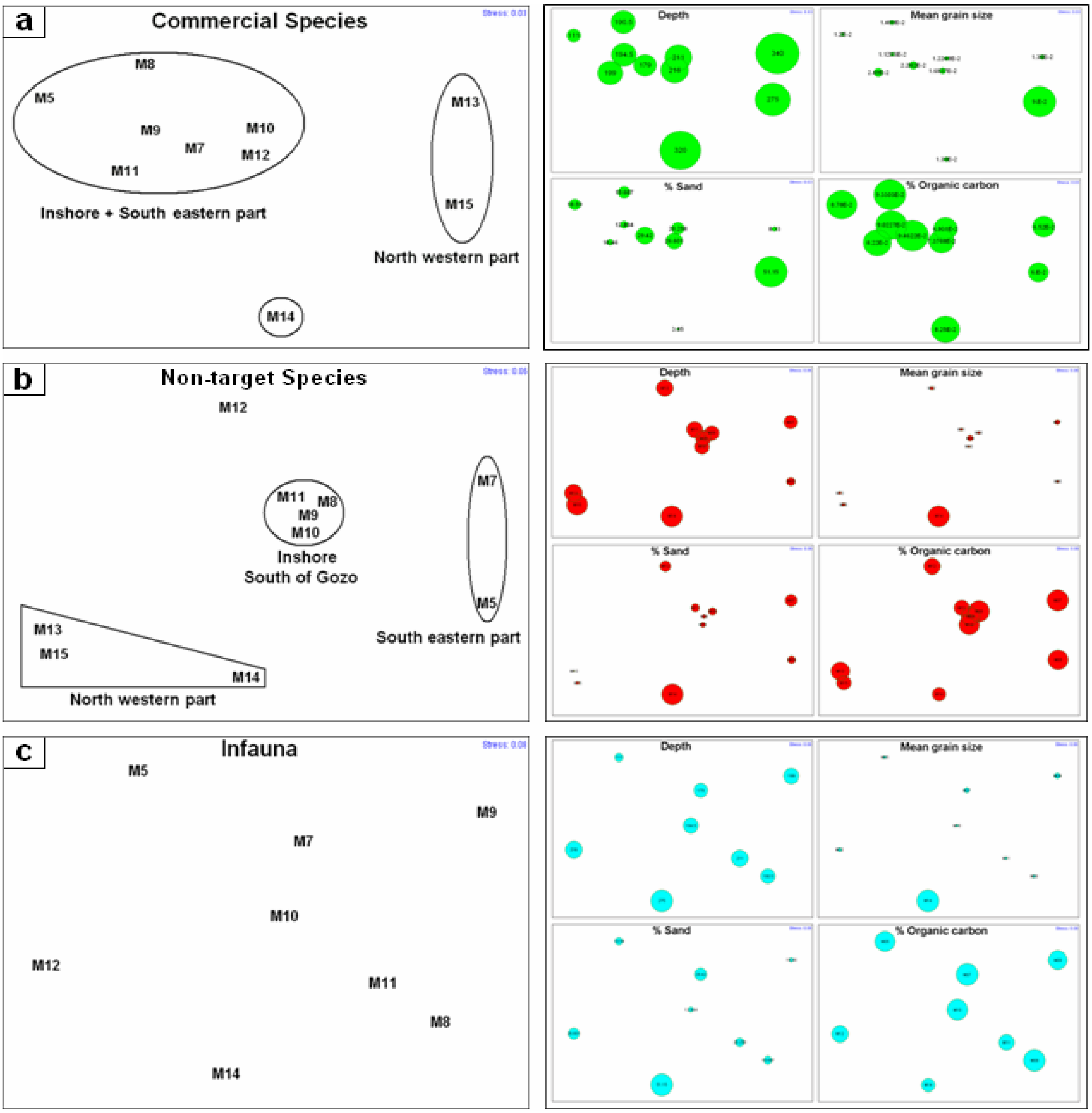

Fig 2. Non-metric multidimensional scaling (nMDS) plot for the ten sampling stations based on fourth root transformed species abundance data using the Bray-Curtis similarity measure. (a) Commercial species; (b) Non-arget specioes, and (c) Infauna. Superimposed plots of scaled values of depth, mean grain size, % sand, % organic carbon are also shown.

Table 1. Mean abundance values of the top ten commercial species from the SIMPER species list, which contributed consistently to the dissimilarity between the inshore + SE sector and the NW sector stations.

Taxon	Inshore + SE		NW	
	Mean abun. (ind. / km^2)	St. dev.	Mean abun. (ind. / km^2)	St. dev.
Aristeomorpha foliacea	0	0	4569	±6310
Trachurus trachurus	0	0	0	0
Illex coindetii	1813	±1705	0	0
Nephrops norvegicus	0	0	856	±524
Mullus barbatus	606	±326	0	0
Galeus melastomus	0	0	236	±283
Phycis blennoides	3	±5	238	±168
Citharus linguatula	401	±589	0	0
Trisopterus minutus capelanus	353	±551	0	0
Aspitrigla cuculus	201	±222	0	0

Table 2. Mean abundance values of the top ten non-target species from the SIMPER species list, which contributed consistently to the dissimilarity between the different geographical locations.

Taxon	Inshore		SE		NW	
	Mean abun. (ind. / km^2)	St. dev.	Mean abun. (ind. / km^2)	St. dev.	Mean abun. (ind. / km^2)	St. dev.
Leptometra phalangium	0	0	10490	±14835	20	±34
Antedon mediterranea	0	0	135	±40	0	0
Parapenaeus longirostris (juv.)	266	±195	4289	±5825	80	±55
Cidaris cidaris	13	±10	220	±80	3	±6
Latreilla elegans	26	±31	122	±173	0	0
Sepia orbignyana	19	±18	0	0	3	±6
Illex coindetii (juv.)	254	±138	655	±806	0	0
Plesionika heterocarpus	0	0	0	0	207	±120
Sergestes corniculum	0	0	0	0	196	±217
Pasiphaea sivado	0	0	0	0	73	±67

The correlation analyses made using the BIOENV program, all gave relatively high values of Spearman's coefficient (Table 3). For all three assemblage types, a combination of three to five abiotic variables gave the highest correlations, with depth, % gravel, % coarse silt, median particle diameter and % organic carbon being the most important.

Discussion

Two different assemblages of commercial species were identified, one in the north-western deeper waters and the other distributed inshore and to the south-east of the Maltese islands. These two areas are both trawled by local fishers. The northern areas are trawling grounds for highly prized decapod crustaceans, namely the Giant Red Shrimp (*Aristeomorpha foliacea*, also commonly called 'King Prawns'), the Norway Lobster (*Nephrops norvegicus)*, and the deep-water Pink Shrimp (*Parapanaeus longirostris*). This area is also characterized by other valuable but locally not commercially important decapod crustaceans such as *Plesionika heterocarpus* and *Pasiphaea sivado*. The inshore and the south-eastern areas are trawled by local fishers mainly for Red Mullet (*Mullus surmuletus* and *Mullus barbatus*), with commercial by-catches of squid (e.g. *Illex coindetti*; *Loligo vulgaris*), Poor Cod (*Trisopterus minutes capelanus*), Hake (*Merluccius merluccius*), Bluemouth Rockfish (*Helicolenus dactylopterus dactylopterus*) and others. The results of our analysis of the commercial catch confirm what local fishers that trawl have known for years, that is, that certain commercial species are commonly present at particular depth ranges and in particular geographical locations.

In the analysis of the non-target species, the northern stations also grouped together as for the commercial assemblage. However, the inshore and south-eastern stations, which grouped together in the commercial catch analysis, were separated in the non-target species analysis

Table 3. Combinations of the twelve variables yielding the best three matches of biotic and abiotic similarity matrices as measured by weighted Spearman rank correlation.

Biotic assemblage	Spearman correlation coefficient	Variable combination
Commercial	0.738	Depth, % Gravel, % Silt &Clay, Median diameter, % Organic Carbon
	0.737	Depth, % Gravel, % Silt & Clay, % Organic Carbon
	0.734	Depth, % Gravel, % Silt, % Coarse silt, % Organic Carbon
Non-target	0.772	Depth, % Coarse silt, % Organic Carbon
	0.771	Depth, % Gravel
	0.771	Depth, % Gravel, % Coarse silt, % Organic carbon
Infauna	0.674	Depth, % Sand, % Very coarse silt
	0.673	Depth, % Sand, % Very coarse silt, Median diameter
	0.673	Depth, % Sand, % Very coarse silt, % Organic carbon

which may suggest a closer association with the environmental attributes across the study area. Most of the non-target species are prey items for the commercial species. The non-target organisms collected by otter bottom trawling are predominantly made up of macrobenthos. A comparison of the the commercial and the non-target components of the samples analysed shows that commercial assemblages residing in different geographical locations may be feeding on two different benthic assemblages (the non-target groups identified by the ordination analysis). Individual commercial species, especially fish, are known to have different diets in different geographic locations according to the availability of prey species within that location (Konstantinos *et al*., 2002). The different non-target assemblages in the inshore and south-eastern stations may be related to different levels of trawling intensity in these two areas. Non-target species, especially benthic organisms, are affected directly by bottom trawling and tend to be less mobile and have longer recovery times (Hall, 1999; Kaiser & De Groot, 2000). In contrast, the commercial catch (especially fish) are usually less sensitive, are more mobile and remain relatively unchanged in terms of their distribution with a moderate level of trawling effort. Commercial species, especially fish, tend to change their feeding behaviour from a predatory to a scavenging one in trawled areas as the fish are attracted by an increased food supply (an energy subsidy) as a result of the mechanical killing of benthic fauna (Demestre *et al*., 2000; Kaiser & Spencer 1994).

The stations to the SE of Malta have a high abundance of the crinoid *Leptometra phalangium* (Table 2). The numbers recorded are an underestimate of the actual population density on the seabed as a large number of the crinoids were probably lost during hauling of the net since these animals are very small (1-3 cm) and pass easily through the net's mesh. Smith *et al*. (2000) also recorded a large number of *Leptometra phalangium* in the vicinity of a trawled area on a muddy bottom at a depth of about 200m in the eastern Mediterranean using underwater video. On the sides of the trawl lane, the crinoids were present in dense aggregations, but the animals were rarely seen in the areas with trawl marks. In trawled areas, suspension-feeders might profit from collecting and feeding on re-suspended sediments, and this might explain the dense aggregations of *L. phalangium* adjacent to trawling lanes; however, these fragile organisms are easily damaged, which explains why they do not occur in trawling lanes (Smith *et al*., 2000).

In the present study, the occurrence of large populations of *Leptometra phalangium* at the south-eastern stations may be related to the presence of trawling lanes in this area as this area may be subject to medium intensity trawling, however, this is still to be confirmed.

Overall, all the stations had a very low infaunal abundance. No fauna whatsoever were recorded from stations M13 (275m) and M15 (340m), to the northwest of the islands (the deepest stations sampled).

Conclusions

For the commercial species two distinct assemblages were found that were largely influenced by geographic location, depth and sediment characteristics. The by-catch component of trawl samples showed similar patterns. However, the inshore and south-eastern stations, which had similar commercial assemblages, had different non-target species assemblages and this may imply a different feeding regime for the commercial species of these two areas. However to confirm this hypothesis, stomach content analyses on selected commercial species needs to be made to determine if the diets of the same species from the two areas are different. The present results suggest that fishing disturbance may cause shifts in the benthic community structure that particularly affect mobile scavenging species, which are probably the most food-limited trophic group on muddy seabeds. The infauna was spatially the most variable component and different stations around the Maltese islands had different assemblages without any clear distributional patterns.

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