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Conservation of the demersal fisheries resources within the 25NM Maltese Fisheries Management Zone

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Conservation of the demersal fisheries resources within the 25NM Maltese Fisheries Management Zone

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To my Family

Abstract

This study investigates the conservation benefits on the demersal resources of the Maltese 25 Nautical Mile Fisheries Management Zone (FMZ) that had been established as an exclusive fisheries zone in 1971 and then as a FMZ after EU accession in 2004. First the relationships between the demersal communities, by-catch species and infauna were examined. Then the study looked at the demersal communities inside and outside the FMZ, at populations and communities within the FMZ under different intensities of trawling pressure and at the fishers' perception of the FMZ.

The commercial demersal assemblages and by-catch within the FMZ were largely influenced by geographic location, depth and sediment characteristics. Certain areas, which had similar commercial assemblages, had different by-catch assemblages and this may imply a different feeding regime for the commercial species but these results need to be confirmed by studying the feeding habits of selected commercial species. The infauna was spatially very variable and this may be due to the low abundance of infauna ca. 64 ind/m^2 and the low number of replicates. The demersal fishery resources on the muddy bottoms of Maltese trawling grounds inside and outside the FMZ are stratified in four main depth ranges: 83–166 m (continental shelf), 140–230 m (shelf break), 270–440 m (shallow slope), and 466–701 m (deep slope). For the continental shelf significant differences were detected between the inside and outside stations of the FMZ with the inside stations having twice as much biomass and larger individuals of some species (e.g. elasmobranchs) than those outside. The depth strata identified also do not coincide with those sampled in the existing trawl survey programme MEDITS in the Mediterranean, which were set up without reference to demersal assemblage structure and its relation to depth and that survey design must take this into consideration.

The ecosystem effects of fishing in the Mediterranean deep sea red shrimp trawl fishery (500 - 800 m) were also investigated at the population and community level by sampling in trawled and non-trawled areas within the FMZ as determined by the Vessel Monitoring System (VMS) fishing effort data for the year 2006 and 2007. At the population level, *Aristaeomorpha foliacea* and *Etmopterux spinax* did not show any differences in biomass while the biomass of *Plesionika martia, Nephrops norvegicus, Helicolenus dactylopterus dactylopterus,* and *Galeus melastomus* was four, sixteen, six and twice respectively as much higher in the non-trawled areas. At the community level higher biomass, density and diversity indices were recorded at the non-trawled areas together with differences in community structure.

The last part of the study examined fishers' perception of the FMZ and investigated if the perceptions depend on fishers' demographic, economic, social characteristics and fishing activity of the fishers using a questionnaire survey. The perception of the commercial fishers was that the establishment of the FMZ has had an overall negative impact on their fishing activity and that the zone is not important for the protection of local fish stocks. However recreational fishers had opposing perceptions. The results suggest that the proportion of individual income derived from fishing was the strongest factor that influenced attitudinal differences. The heterogeneity among fishers' attitudes revealed by the study indicated that the implementation of spatial closures may gain inherent acceptance from some sectors of the industry, while others may require additional incentives to accept such schemes.

Relevant scientific seminars and conferences were regularly attended at which work was often presented; external institutions were visited for consultation purposes and papers prepared for publication.

Publications:

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Dimech, M., Camilleri, M., Kaiser, M., Schembri P. J., (2007). Demersal assemblages on deepwater trawling grounds off the Maltese Islands: Management implications. Rapp. Comm. int. Mer Médit., 38, 2007

Dimech, M., Camilleri, M., Kaiser, M., Schembri P. J., (2007). Role of environmental variables in structuring demersal assemblages on trawled bottoms on the Maltese continental shelf. Rapp. Comm. int. Mer Médit., 38, 2007.

Dimech M, Camilleri M, Hiddink J G, Kaiser M J, Ragonese S, Schembri P J, (2008). Differences in demersal community structure and body-size spectra within and outside the Maltese Fishery Management Zone (FMZ). Scientia Marina, 72(4): 669-682.

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Signed .... (candidate)

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The data presented in this work was gathered through the Mediterranean International Trawl Survey (MEDITS) in which I was deeply involved from the sample collection on board the reaseach vessel to the analysis of the samples in the laboratory. However due to the large amount of samples collected, several personell were involved in the sample collection and processing all of which I have acknowledged above.

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Chapter 1

General Introduction

As in most parts of the industrialised world the Mediterranean has a long history of fishing and most of the Mediterranean bottom trawl fisheries can be considered as highly exploited. Most of the major impacts of bottom towed gear (namely otter trawls, beam trawls and dredges) recorded around the world occur also in the Mediterranean. Although literature was reviewed from studies in various regions of the world, this work was focused on the research carried out in Mediterranean marine ecosystems. An account of the Mediterranean ecosystems is also given with special reference to deep water ecosystems, due to the particular conditions in the Mediterranean (e.g. relatively high temperate, high salinity and oligothrophy). Where information related to some of the major issues is scarce, special attention has been devoted to the few studies available, given their qualitative importance.

The Mediterranean International Trawl Survey (MEDITS) is reviewed in quite some detail since most of the data for the PhD degree will be derived form the MEDITS survey in the Sicilian channel. A background of the Maltese Fishing industry and the Maltese 25 nautical mile Fisheries Management Zone (FMZ) is also given in the context that the project directly involves the management of the FMZ, and its implications in the management regime of demersal resources in the strait of Sicily.

1.1 The Mediterranean basin

The Mediterranean contains sea-beds up to 5000 m deep and the maximum depth is 5121 m in the Matapan-Vavilov Deep, off the Southern coast of Greece, with an average depth of 2500 m. The Mediterranean sea harbours most of the same key geomorphologic structures – such as submarine canyons, seamounts, mud volcanoes or deep trenches – that have proven to translate into a distinctive biodiversity makeup in other regions in the world; recent findings have indeed confirmed this (including the presence of chemosynthetic trophic webs). A further unique feature of the Mediterranean is that it harbours one of the few warm deep-sea basins in the world, where temperatures remain largely uniform at around 12.5-14.5°C at all depths, with high salinity (38.4-39.0 PSU) and high oxygen levels (4.5-5.0 ml/L; Miller *et al.*, 1970; Hopkins, 1985). The constant temperature and salinity regime of the Mediterranean contrasts with the Atlantic at comparable latitudes, where temperature decreases and salinity increases with depth. Another important issue is the relative isolation of deep-sea communities, not only with respect to those of the Atlantic (the maximum depth of the sill of Gibraltar is ca. 300 m), but also between those in the Eastern and Western Mediterranean, separated by the shallow Sicilian Channel (ca. 400 m, Fig. 1.1). All these features reinforce the potential for unique deep-sea communities in the Mediterranean, and the importance of precautionary action to limit the impact of human activities on these fragile habitats. Especially in the last decade where, deep-sea ecosystems are now the ultimate target of industrial fisheries worldwide, following the relentless depletion of fish communities on the continental shelves, in a sort of "(over)fishing down the bathymetric range" effect (Merrett and Haedrich, 1997).

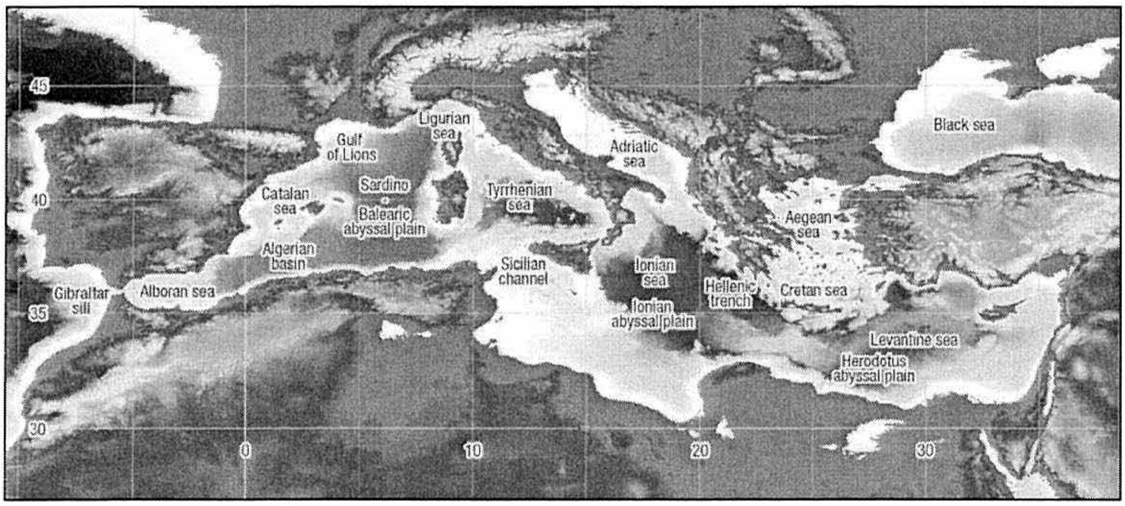

Figure 1.1 Geography of the Mediterranean sea (from GEBCO, 2003).

The continental shelves, where most commercial fishing activity is conducted, cover only 30% of the Mediterranean area, while the bathyal domain covers 60% and the abyssal plain the remaining 10% (approx.). Continental shelves are only extensive near the major river mouths (the Rhone in the Gulf of Lions, the Nile in the Levantine sea), or on the Adriatic basin and the Siculo-Tunisian sill. A large part of the Mediterranean coast has deepwater beds very near shore, typically a few hours away by commercial vessel. Although fishing for continental shelf resources dates back to ancient times, commercial fisheries in the bathyal domain started only in the early decades of the 20th century, and have increased in importance since the 1950's, especially on the Ligurian, Catalan, Balearic and Sicilian coasts (Sardà *et al.*, 2004). The development of deepwater commercial fisheries was linked, as in other seas, to the development and motorization of trawler vessels. For example deep-water fisheries in the Mediterranean using deepwater trawlers target red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*) between 400 - 800 m and sporadically down to 1000 m.

Certain areas of the Mediterranean deep-sea are benthic diversity hotspots because they harbour special faunas rich in endemic taxa. Hydrothermal vents, cold seeps, cold-water coral reefs (Mastrototaro *et al.*, 2002; Tursi *et al.*, 2004, Schembri *et al.*, 2007) and other habitats, such as seamounts (Rogers, 1994; Koslow, 1997; Galil and Zibrowius, 1998) and submarine canyons (Bouillon *et al.*, 2000; Gili *et al.*, 1998; 2000), have been identified as diversity hotspots.

1.1.1 Structure of deep-sea Mediterranean communities

Two main biocenoses ("facies") in the deep Mediterranean have classically been defined (Pérès, 1985):

i) soft-bottom communities;

ii) hard-bottom communities.

The transition between the circalittoral and bathyal domains in the Mediterranean occur at around 180-200 m depth. Depending on the nature of the sediment (which depends in turn on factors such as hydrodynamism and mainland influence), three horizons were established by Pérès (1985) in the soft-bottom communities: the upper, middle and lower slope horizons. The upper slope horizon is a transition zone between the coastal zone and bathyal domains, comprising a large share of eurybathic forms and extending to 400-500 m deep. The sea pen *Funiculina quadrangularis* and the crustaceans *Parapenaeus longirostris* and *Nephrops norvegicus* are characteristic species of this horizon. The middle slope horizon, characterized by firmer and more compact muds, is the zone where most taxa achieve maximum diversity. For fish and decapods, in the NW Mediterranean, this horizon extends to a depth of 1200-1400 m. The cnidarian *Isidella elongata*, the crustaceans *Aristeus antennatus* and *Aristaeomorpha foliacea* are characteristic examples. The lower slope horizon is not so well studied, but some characteristic megafaunal species can be listed: decapods, such as *Stereomastis sculpta*, *Acanthephyra eximia* and *Nematocarcinus exilis*, and fishes, such as *Bathypterois mediterraneus*, *Alepochephalus rostratus*, *Lepidion lepidion* and *Coryphaenoides guentheri*.

Hard bottoms are represented below 300 m and down to 800-1000 m, in areas where high hydrodynamism precludes sedimentation and exposes bare rock. In the northern Ionian sea (Santa Maria di Leuca) a unique biocenose of white corals has been reported from 450-1100 m depth (Mastrototaro *et al.* 2002; Tursi *et al.* 2004) and recently also in Maltese waters (Schembri *et al.*, 2007). Live colonies of *Madrepora oculata* and *Lophelia pertusa* were found, with a rich epibiont fauna. These species occur elsewhere in the Mediterranean as fossils or subfossils (Zibrowius, 1980; Pérès, 1985).

In the marine environment, depth is assumed as the major forcing factor structuring communities: species assemblages and communities show more variability vertically, as a function of increasing depth, than over the horizontal dimension (Haedrich *et al.*, 1975; 1980; Cartes and Sardà, 1993; Stefanescu *et al.*, 1994). This observation suggested the idea of the zonation phenomenon: depth bands of high faunal homogeneity separated by boundaries of faunal renewal. Species are usually distributed along ecological gradients in a bell-shaped curve, and this is also observed with diversity. Ecological theory and observations show that species are distributed along environmental gradients (see e.g. Ter Braak and Prentice, 1988), having a different habitat amplitude or centre of gravity in their distribution (Stefanescu *et al.*, 1994, for a Mediterranean deep-sea example). Along a depth gradient, species show also a minimum and maximum depth of occurrence, with an intermediate depth, the Depth of Optimal Abundance (DOA), where their density is the highest. Species may find better living conditions, i.e. trophic requirements, at this DOA, as a consequence of an adaptive success to the environment. In deep-Mediterranean fish assemblages, for instance, most fish species showed an increase in their trophic diversity associated with the DOA (Carrassón and Cartes, 2002). Boundaries of faunal change have been described in deep ecosystems, both at bathyal and abyssal depths. Most deep-Mediterranean species have a eurybathic distribution. This is probably due to the high thermal (13-13.5°C in the western basin; 14-14.8 °C in the eastern basin) and saline (38.5-38.6 PSU) stability of the water mass below 150 m in the deep Mediterranean (Hopkins, 1985). Pérès (1985) already proposed a pattern of change with depth for deep Mediterranean fauna. Although with important local variations, a faunal renewal belt between the upper and middle part of the slope appears recurrently between 300 and 700 m for megafaunal assemblages, both in oceanic regions and in the Mediterranean, and in the deep Catalan Sea (north-western Mediterranean) at ca. 500 m depth (Abelló *et al.*, 1988; Cartes *et al.*, 1994). A second, deeper, boundary between 1000 and 1400 m has also been reported in deep sea ecosystems (Haedrich *et al.*, 1980; Cartes and Sardà, 1993) and, in the deep Mediterranean, it separates the middle and lower slope assemblages (Pérès, 1985; Cartes and Sardà, 1993). Due to the particular paleoecolgical conditions of Mediterranean biota, and the lack of a thermal gradient below 150 m, the boundary between bathyal and abyssal depths has not been clearly identified. Each depth assemblage is characterized by its own levels of biomass, production and faunal diversity. Most studies available are descriptive in nature, with little data trying to relate changes in faunal assemblages with environmental variables that could explain possible zonation patterns. Therefore, possible causes for species distribution are far from being fully established. Some differences in zonation patterns have been found depending on the trophic level of each taxon. Distinction between zones regularly increase with trophic level (Rex, 1977), and, in the western Mediterranean, lower rates of zonation were found in peracarids (belonging to a low trophic level) compared to fish and decapods. Trophic and biological causes may explain, in a thermally stable environment, patterns of distribution and zonation of deep-sea Mediterranean species.

1.2 Bottom trawl Fishery in the Mediterranean

Deep-sea fishing is a relatively new phenomenon, and expanding in various parts of the world. In the Mediterranean it has become relatively important since the 1940-50's due to the high commercial value of deep sea shrimps (mainly *Parapenaeus longirostris*, *Aristeus antennatus* and *Aristaeomorpha foliacea*). Bottom trawling fleets predominate in many Mediterranean fisheries, being responsible for a high share of total catches and, in many cases, yielding the highest earnings among all the fishing sub-sectors. The high profitability of this fishing practice is largely due to its low selectivity with respect to sizes and species caught, and to the high harvests generated. Bottom grounds of Mediterranean Sea are trawled for commercial fishing at depths ranging from 50 to 800 m (Farrugio *et al.*, 1993; Papaconstantinou and Farrugio 2000). The fishery is characterized by a multi-species composition, where many commercial species appear seasonally in the catches (Caddy, 1993; Stergiou *et al.*, 1997). Trawl catches are composed of a highly diversified mix of fish (teleosteans and elasmobranchs), cephalopods and crustaceans (decapoda and stomatopoda), together with several epifaunal macrobenthic species (Relini, *et al.*, 1999). However, some of the species, due to their abundance and their economic value, are to some extent target species (Oliver, 1993). The Mediterranean fisheries from 100 – 200m depth target mainly red mullet (*Mullus surmuletus* and *Mullus barbatus*). In the upper slope (down to ca. 500 m), the "deep-water" pink shrimp *Parapenaeus longirostris* and the Norway lobster *Nephrops norvegicus* represent important fisheries in certain areas. These fisheries have important quantities of other commercial species which are also to certain extent targeted, such as *Merluccius merluccius*, *Micromesistius poutassou*, *Conger conger*, *Phycis blennoides* and, to a lesser extent, monkfish (*Lophius* spp.) and the cephalopods *Todarodes sagittatus* and *Illex coindetti*. The by-catch of other decapod crustaceans is increasingly commercialised including the glass shrimp *Pasipahea* spp., *Acanthephyra eximia*, *Plesionika* spp., *Geryon longipes* and *Paromola cuvieri*.

Deeper fisheries (approx. 400 m to 800 m) target almost exclusively aristeid shrimps (*Aristaeomorpha foliacea* and *Aristeus antennatus*), though some hake is also harvested. In the Greek waters and central Mediterranean, *A. foliacea* is more abundant than *A. antennatus*. However, deep-water fisheries (> 500 m) are not yet well-developed in Greece (Mytilineou and Politou, 1997; Politou *et al.* 2003). Beds deeper than 1000 m can be considered virgin from the viewpoint of commercial exploitation of living resources and given the state of continental shelf fish resources the fishing industry is directing more attention towards the potentially exploitable living resources of the deep-sea.

1.2.1 Assemblage structure in Mediterranean trawled fishing grounds.

Demersal fish, crustacean and cephalopod assemblages in Mediterranean trawled fishing grounds have been widely studied in the western, (Demestre *et al.*, 2000a; Abelló *et al.*, 2002; Massuti and Renones 2005) central (Abella *et al.*, 1999; Ungaro *et al.*, 1999; Collaca *et al.*, 2003) and eastern (Tserpes *et al.*, 1999; Labropoulou and Papaconstantinou, 2000; Kallianiotis *et al.*, 2004) Mediterranean bottoms. Some studies have also studied the relationship between environmental factors (i.e. depth, water temperature, oxygen concentration and sediment type) and the distribution of the demersal assemblages (Biagi *et al.*, 1989; Farina *et al.*, 1997). Others have attempted to relate the demersal assemblages to the structuring role of macroepibenthic communities (Gaertner *et al.*, 1999, 2002; Collaca *et al.*, 2003).

Most of these studies suggest that depth gradient is the most significant parameter for the definition of demersal assemblages. Cephalopod associations were found strongly influenced by depth (Gonsalez and Sanzes, 2002), where strictly coastal species, species living on the slope and other species without any specific distribution pattern were caught. The same bathymetric trend was found in the Gulf of Lion (Gaertner *et al.*, 1999, 2002), considering the main species of fish, crustacean and cephalopods. In this region three sub-areas were defined, the first on the continental shelf, the second from the shelf edge to the upper slope (200–500 m) and the third in the deeper slope (500–800 m). Some regional species exhibited strong variability in their spatial distribution.

In the Tyrrhenian Sea off the coasts of Tuscany, a similar species distribution was found according to the depth gradient, dividing the area in two distinctive bio-geographic areas one in the continental self and the other in the slope. The persistence of the defined assemblages through time was the main characteristic of the area (Biagi *et al.*, 2002). In the central Mediterranean a well defined difference in macroepibenthic faunal associations on the slope (depth > 200m) was not found. However a strong correlation was found between epifaunal benthic communities and demersal fish assemblages (Colloca *et al.*, 2003).

All of these studies are important for the formulation of an ecosystem based management for the Mediterranean trawl fisheries and the existence of a relation between environmental factors, epibenthic invertebrates and demersal species may have a crucial importance for such management, considering the increasing knowledge about the impact of trawling on the marine ecosystems (Kaiser & De Groot, 2000).

1.2.2 Bottom trawling in the Sicilian Channel

The Strait of Sicily appears to be one of the most important fishing areas for demersal resources in the Mediterranean, as witnessed by the important fleets operating there and the associated fish production. According to Levi *et al.* (1998), the Italian fleet operating in the Strait of Sicily consists of about 615 trawlers based in Sicilian harbours. The Sicilian trawlers, operating mainly in a short-distance trawl fishery, are based in seven main ports along the southern Sicilian coast, (Andreoli *et al.* 1995). Among them, Mazara del Vallo represents the main commercial fleet of trawlers of the area and one of the most important in the Mediterranean (Levi *et al.* 1998). Unlike the other Sicilian fleets, about 140 large trawlers (mean GRT about 130) of the Mazara fleet, 60 usually engage in long fishing trips (15–25 days) within the national and in the international waters of the Strait of Sicily, operating over the continental shelf and over deep bottoms (down to 700–800 m depth). The remainder of the Mazara fleet comprises 40 small trawlers (<130 GRT) that make short fishing trips (4–5 days) operating in shallow waters and on the continental shelf. The fleet has exploited the trawlable inshore and offshore grounds of the Strait of Sicily for the last 40 years (Levi *et al.*, 1998). Important changes occurred in this fleet during the late 1980s and early 1990s when many old vessels, primarily used for coastal trawling, were demolished and larger trawlers, for fishing in distant waters, were built (Andreoli *et al.*, 1995). Although an overall reduction in the fishing capacity of the Sicilian fleet, in terms of number of trawlers, occurred in the late-1980s–early-1990s, an analysis of the trawler composition in the period 1995–1999 showed that the number of vessels was fairly stable, with a slow, but constant, increase in the mean engine power (in kW) and GRT (from 128 to 133) (Anon. 2000).

Changes of the fleet, and technological improvements in navigation and fishing equipment, lead to a southward expansion of the fishery. New fishing grounds, included the north African shelf, were forced by the overexploitation of resources in the Italian side of the Strait of Sicily (Levi *et al.*, 1998). At present, the southern limit of the Mazara del Vallo fleet operation area is about 50 nautical miles off the Libyan coast, while the eastern border is delineated by the line that links Malta to the Libyan coast.

The spatial and temporal distribution of the fishing effort exerted by this fleet is patchy, with some zones fished intensively all year around and others lightly fished (Fiorentino *et al.*, 2004).The areas in which the fleet fish include parts of all the General Fisheries Commision of the Mediterranean (GFCM) geographical sub-areas (GSAs 12, 13, 14, 15, 16 and 21) into which the Strait of Sicily is divided (Anon. 2000). All the boats of the Mazara del Vallo fleet use the same type of trawl net, known as the "Italian trawl net". Although there are some differences in material between the net used in shallow water ("banco" net) and that employed in deeper ones ("fondale" net), the Italian trawl net is characterized by a low vertical opening (up to 1.5 m) with dimensions depending on engine power (Anon. 2000). Recently, the minimum stretched-mesh size of 28 mm opening was changed to 40 mm, which is the minimum legal size recommended by GFCM for the whole Mediterranean. Rough data on fishing effort and on the spatial distribution of the Mazara del Vallo trawl fleet refer only to a 5-year survey (the Discard Programme Anon. 2000), based on interviews with captains and crews of a representative set of vessels (Anon. 2000). On the basis of this information, a picture of the distribution of the commercial activity of the Mazara del Vallo trawl fleet and of the fluctuation of the fishing pressure in the Strait of Sicily is available. As noted by Andaloro (1996), eight main fishing areas were identified. The fishing pressure seems to be concentrated in two areas with seasonal fluctuations due to the abundance of target species with high commercial value, especially *Aristaeomorpha foliacea* in spring and summer and *Mullus surmuletus* in autumn (area H) (Figure 1.5).

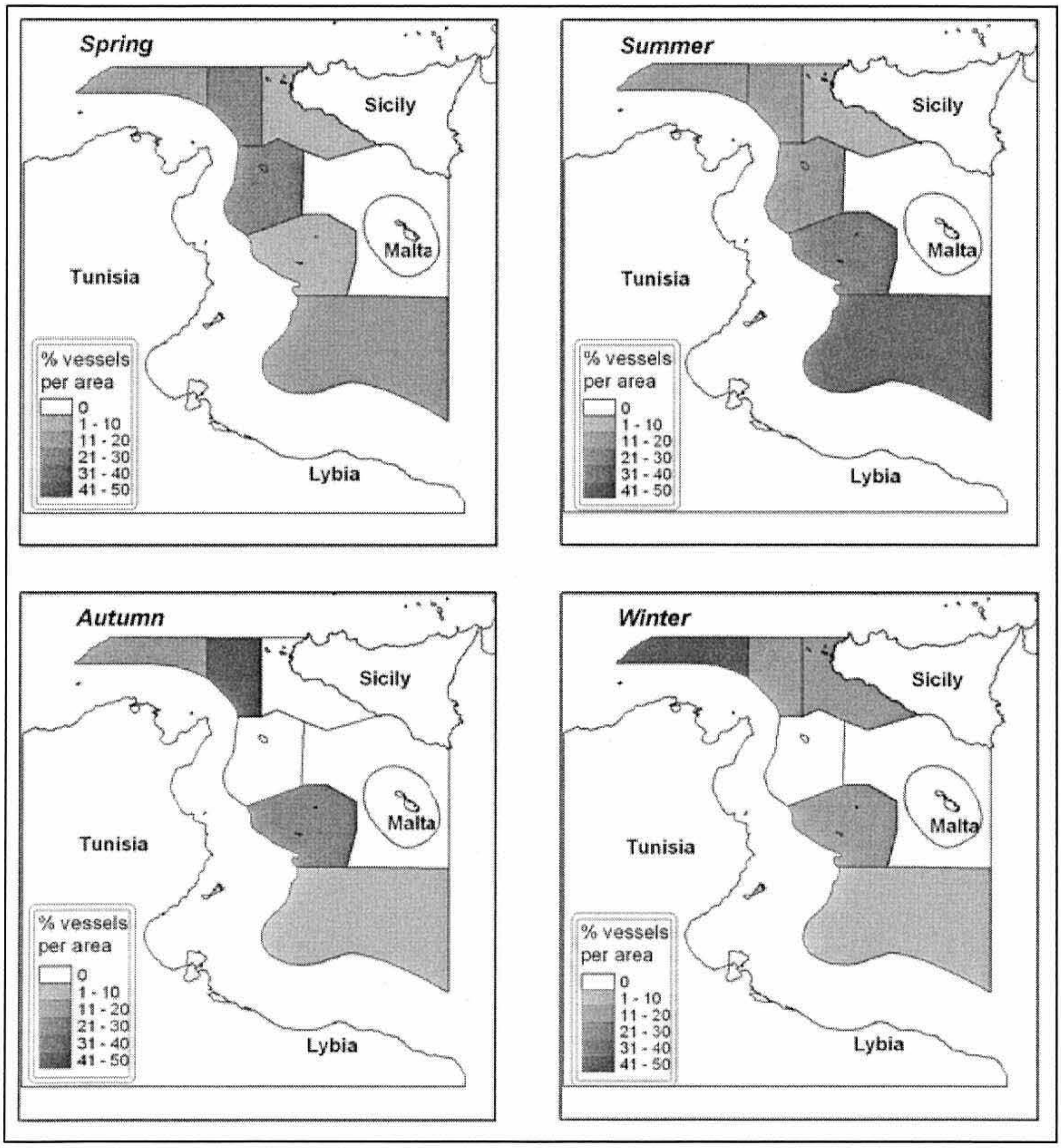

Figure 1.2 Seasonal distribution of the fishing pressure in the strait of Sicily (Anon 2000)

1.2.3 The Mediterranean International Bottom Trawl Survey – MEDITS

In the Mediterranean, the main demersal fisheries are localized on narrow continental shelves along the coasts. As most of the benthic and demersal fish stocks are defined and exploited at national level, and as exploitation is strongly distributed in a wide regional area it was difficult to obtain a global estimate of the demersal resources from fishing activity, especially due to the very large dispersion of the landing places, the important diversity of the species caught and the scarceness of reliable statistics. To support the regulation of these fisheries, particularly for the application of the common fishery policy in the Mediterranean, there was a need for standardised information on the status of these resources. This situation has induced different European Union member states to conduct international programmes for the assessment of these resources from repetitive trawl surveys. The need for this work has been confirmed during a Diplomatic Conference on the fishery management in the Mediterranean. To complete this job, different institutes from four partner countries (Spain, France, Italy and Greece) gathered together in 1993 to build the Mediterranean International Bottom Trawl Survey (MEDITS) programme. The programme was then managed by the four main partners respectively in each of the four Mediterranean European countries, the Spanish Institute of Oceanography (IEO, Spain), the French Research Institute for the Exploitation of the Sea (IFREMER, France), the Italian Society of Marine Biology (SIBM, Italy) and the Greek National Centre of Marine Research (NCMR, Greece) but later also included other new member states. Those partners have been chosen for their own competency and their ability to mobilize at the national level the technical and financial means required for the programme. In each of the countries, regional co-ordinations were defined when necessary. A general co-ordination is assumed by one of the four main partners (IFREMER since the beginning of the programme till now). Since 1996, the activity of the programme has been enlarged in the Adriatic through the participation of three newcomer countries Albania, Croatia, Slovenia and in the eastern Mediterranean by Cyprus. Malta has joined the survey since 2000. For the time being, about twenty institutes and laboratories from the Mediterranean contribute in the programme.

In some Mediterranean areas, national programmes of bottom trawl surveys were also carried out routinely since the early eighties, for example, the Italian national trawl survey GRUND (GRUppo Nazionale Demersali) which has been conducted since 1984 (Relini 2000). All these programmes were designed with protocols defined at local level. When the partners decided to organise the MEDITS survey, one of the main challenges of the project was the adoption of a common standardized sampling protocol, which could also permit the enlargement of the programme to other Mediterranean countries. The basic protocols have been adopted by the first four partners early in 1994, just before the first survey.

These standardized protocols include the sampling gear (feature and handling), the design of the survey, the information collected and the management of the data as far as the common standard analysis of the data. Before the first survey, all the common protocols have been brought together in a "Manual of protocols" (Bertrand *et al.*, 1994) agreed by the Steering Committee of the programme, distributed to the participants before the first survey (1994) and published later (Anon., 1998) to ensure its distribution. This manual has been established from different experiences, and particularly the one of the IBTS Group (ICES 1992). The protocols have been amended when necessary and particularly in 1995 to take into account the experience gained during the first survey. Two publication describing the MEDITS surveys were published a few years ago (Bertrand *et al.*, 2000; Bertrand *et al.*, 2002), which describe the main specifications of the programme and present its evolution since 1998.

1.2.3.1 Working area

In general the MEDITS programme was designed with the following basic aims:

i) to contribute to the characterization of bottom fisheries resources in the Mediterranean in term of population distribution (relative abundance indices) as well as demographic structures (length distributions, maturity stages, etc.) and,

ii) to provide data for modelling the dynamics of the studied species.

In this scope, estimation of total mortality of the exploited species constitutes an important aim. The programme had also to take into consideration different observations. A simple analysis of the geography and the bathymetry of the zone show the very great diversity of the different sub-areas. For example, one can underline differences of hydrological conditions between the waters in the Alboran sea marked by the Atlantic influence and those in the Aegean sea, in direct contact with the Black sea, or the relative monotony of bottoms of the High Adriatic opposed to their very wild aspect in the Aegean sea. Finally, the diversity of the exploited species contributes to the fisheries' wealth in the Mediterranean. If a limited number of species produces an important part of the landings value, the existence of this great species diversity needs however a special attention for the fishery management in the area.

One of the general aims of the MEDITS programme is also to conduct co-ordinated surveys from bottom trawling in the Mediterranean Sea. So far, the surveys cover all the trawlable areas over the shelves and the upper slopes from 10 to 800 m depth in the sampled area. The working zone is defined as the totality of the trawlable areas off the coasts of the partners' countries (Fig. 1.6), from 10 to 800 meters. These limits have been adopted to cover at best the distribution areas of the main exploited - or potentially exploitable - species, considering the administrative and technical constraints of the project. The first two surveys (1994 and 1995) have been conducted only along the coasts of Spain, France, Italy and Greece. In 1996 the area was enlarged to cover almost all the Adriatic sea (including Slovenian, Croation and Albanian waters). The South of the Albotran sea has been included in the survey programme since 1999 (the Morocccan contribution), the waters around Malta since 2000 and the waters around Cyprus since 2005.

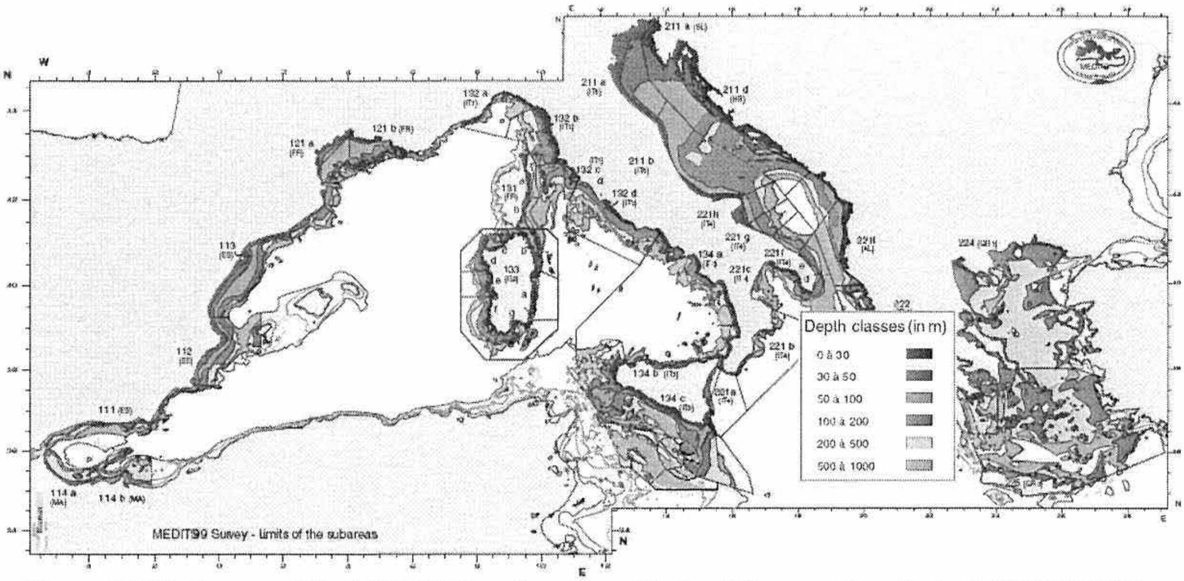

Figure 1.3 Study area of the MEDITS trawl surveys. Limits of the sampling strata (MEDITS 2004)

The stations have been distributed applying a random stratified sampling scheme. The stratification parameter adopted was the depth, with the following bathymetric limits: 10, 50, 100, 200, 500 and 800 meters. Each position has been selected randomly in small sub-areas defined so as to get a compromise between the constraints of statistics based on random sampling and those of geostatistics (Green, 1979; Hilborn and Walters, 1992).

The foreseen average sampling rate is one station per 60 square nautical miles in all the areas except in the Adriatic where it is laid down to one station per 200 square nautical miles because of the relative homogeneity of the substratum. The same positions are sampled each year with small changes every 4-5 years. A total of about one thousand hauls are carried out during each annual survey. Taking into account the total trawlable surface area (504, 000 km^2) in 2004 and the surface swept area during each haul, the average ratio of surface sampled by survey is about 0.026%. Since 1994 one survey has been carried out every year, during the spring and in the beginning of summer. To reduce the duration of each survey, several boats (8 to 11 vessels according to the year) work at the same time. Each of these vessels work at sea for about one month per year. Research vessels and chartered fishing vessels are used depending on local possibilities. As much as possible the same vessel was used every year in each area. The duration of the hauls is fixed to half an hour on depths less than 200 meters and one hour on deeper bottoms.

1.2.3.2 Sampling gear

All the hauls are carried out using the same sampling gear. The standard device is a bottom trawl, including all the material and its rigging from the doors to the coded end of the net. The chosen gear (GOC 73) is a bottom trawl (Fiorentini *et al.*, 1999) designed for experimental fishing with scientific purpose. It achieves a compromise between different constraints. In particular, the characteristics of this gear make it usable over the depth range and in the various conditions encountered in the whole area. To increase the catch of demersal species, it has a vertical opening slightly superior to the most common professional gears used in the area. Its codend mesh size is 20 mm (stretched mesh).

The design of the gear has been drawn up by fishery technologists (P.Y. Dremière, IFREMER-Sète) from specifications defined by the biologists. The gear has been tested from a model in an artificial flume tank then in real conditions at sea, before its production for the first survey. Then, specific studies have been conducted to complete the knowledge about the efficiency of the gear (Fiorentini *et al.*, 1996; Fiorentini and Dremiere, 1996; Fiorentini *et al.*, 1999). When necessary the sampling gear and its handling have been slightly modified to improve its performances, especially to better stabilise it when contacting the bottom. The modifications have been decided as much as possible to limit their effects on the series consistency, but improving their quality. The main improvements were applied just before the 1995 survey (Fiorentini *et al.*, 1996). At that time the results of the survey had shown that the contact of the gear with the bottom was not fully satisfactory, especially along the slopes (depths of over 200m). To improve this contact, buoyancy at the headline was reduced, links between the net and footrope were shortened, the sweeps were reduced, and rules for hauling were modified. As a secondary consequence, the vertical opening of the gear has been reduced (from an average of 3 to 2.5 m) and the average wide opening enlarged consequently. Furthermore the tickler chain was removed in 1995 over the slopes and everywhere in 1996. A device to follow the geometry of the gear was systematically used only aboard some of the sampling vessels since the beginning of the survey series. Aboard the other vessels, only preliminary tests were conducted with this type of device at the beginning of the first surveys. Since the 1998 survey, an autonomous recording probe was systematically added along the headline aboard all the vessels to record water temperature and at the beginning and end of hauls. The device used (Venmco Minilog) also recorded depth during the hauls. A first analysis of the gear trajectory described from these recordings (Bertrand *et al.*, 2002) has shown that some progress is yet to be done to better standardize the distance really swept by the gear at the deepest locations.

1.2.3.3 Target species and data collected

A list of common target species (including fish, molluscs and crustaceans) was established with reference to their commercial production, their accessibility for a bottom trawl and their potential interest as biological indicator in the different areas. The reference list of species defined at the beginning of the programme included thirty species. It was enlarged to thirty four species during the following years (Table 1.1). Observations on these species are the total number of individuals, total weight, length frequency distribution and sex (including sexual maturity stage). The characteristics of each kind of observation are specified in the manual of protocols (Anon. 2007). For all the other species of commercial interest (fish, crustacean and mollusc), the total number and total weight are collected for each haul. During each annual survey, a total of approximately 150 species are identified onboard each of the vessels.

The data are put in computer files by the teams in charge of the survey. Four standard exchange formats (in ASCII) including normalized coding are defined. A specific software has been written (Souplet, 1996a) for an automatic checking of the data. Recently a new software SEATRIM (Software for the Exploratory Analysis of TRawls Information in the Mediterranean) was also developed from the Italian partner for inputing and the preliminary analysis of the data (De Santi *et al.*, 2003). This checking is done by each of the partners for its own data before their regrouping. After a second validation in the regrouping place (IFREMER-Sete), copies of the total set of data files are deposited on CD-ROM at the Co-ordinators and EC-DG Fish offices. The process is managed such as to make the data bank available a few months after the end of each survey.

Table1.1 Target species included in the MEDITS reference list	
Species	**Common name**
Aspitrigla cuculus	Red gurnard
Chelidonichthys gurnardus	Grey gurnard
Chelidonichthys lastoviza	Rock gurnard
Citharus linguatula	Spotted flounder
Galeus melastomus	Blackmouth catshark
Helicolenus dactylopterus dactylopterus	Bluemouth rockfish
Lepidorhombus boscii	Four-spotted megrim
Lophius budegassa	Lesser anglerfish
Lophius piscatorius	Greater anglerfish
Merluccius merluccius	Hake
Micromesistius poutassou	Blue whiting
Mullus barbatus	Red mullet
Mullus surmuletus	Striped mullet
Peristedion cataphractum	Armed gurnard
Phycis blennoides	Grater forkbeard
Raja clavata	Thornback ray
Raja miraletus	Brown ray
Scyliorhinus canicula	Small-spotted catshark
Spicara flexuosa	Small spotted picarel
Spicara smaris	Picarel
Trachurus mediterraneus	Med. horse mackerel
Trachurus trachurus	Atlantic horse mackerel
Trisopterus minutes capelanus	Poor-cod
Zeus faber	John dory
Aristeomorpha foliacea	Giant red shrimp
Aristeus antennatus	Blue and red shrimp
Nephrops norvegicus	Norway lobster
Parapenaeus longirostris	Deep-water pink shrimp
Eledone cirrosa	Horned octopus
Eledone moschata	Musky octopus
Illex coindetti	Broadtail squid
Loligo vulgaris	European squid
Octopus vulgaris	Common octopus
Sepia officinalis	Common cuttlefish

A specific chart defines the rules for the distribution of the MEDITS data. From this chart, the full access to the raw data bank is guaranteed to the European Commission and the laboratories participating in the surveys. This access is managed through the concerned national co-ordinators of the project. The Co-ordination committee must be informed of projects intending to use raw data from the international data bank. Other users may freely use the aggregated data presented in the reports produced by the MEDITS group.

At the end of each survey, standard analyses are produced on the data. These analyses include the production of biomass and abundance indices (in kg/km^2 and in number of individuals per km^2) as well length frequency distributions by species and strata. These analyses are made using statistical methods approved by the Steering Committee.

1.2.4 MEDITS and GRUND trawl surveys in the Strait of Sicily

In the Strait of Sicily the MEDITS and GRUND trawl surveys represent the main source to obtain information about standing stock, biology and exploitation status of bottom-dwelling populations exploited by distant trawling (Levi *et al.*, 1998). Sampling at sea in the Strait of Sicily has been conducted always with the same vessel since 1985. It is a commercial stern trawler (Sant` Anna) harboured in Mazara del Vallo (built in 1981; 32.2 m of length, 197.1 t, powered with an engine of 736 KW (1012 HP), 750 max. gyres, colour echo sounder, and 2300 m of trawl warp). The trawler can host up to 15 persons including the scientific staff.

Two types of bottom trawl gear are used, GOC 73 (MEDITS) and the typical "Mazarese" commercial "tartana di banco" (GRUND). The two nets mainly differ in the vertical opening of the mouth: 2.4-2.9 m (MEDITS) and 0.6–1.3 m (GRUND). Some adjustments were done for both MEDITS (in 1995) and GRUND (in 2000); in the GRUND net, in particular, the previous cod-end (mounting 31mm diamond stretched mesh size) was replaced by a new ad hoc designed cod-end mounting the same MEDITS mesh size (20 mm, stretched). The use of special device to close the cod-end at a given depth was foreseen only in MEDITS programme (CodEndC; "N" by default), but never employed in the Strait of Sicily. As concern the otter doors original rectangular wood and iron polyvalent boards have been used in GRUND and MEDITS respectively since the beginning of both programs.

1.2.4.1 Areas investigated by the MEDITS and GRUND trawl surveys

Formerly four traditional principal subdivisions of the Strait of Sicily were present which were considered within the GRUND and MEDITS trawl surveys (the waters inside, A, outside, B-C, the midline, and the Maltese Fisheries Management Zone, FMZ or D; see Fig 1.7).

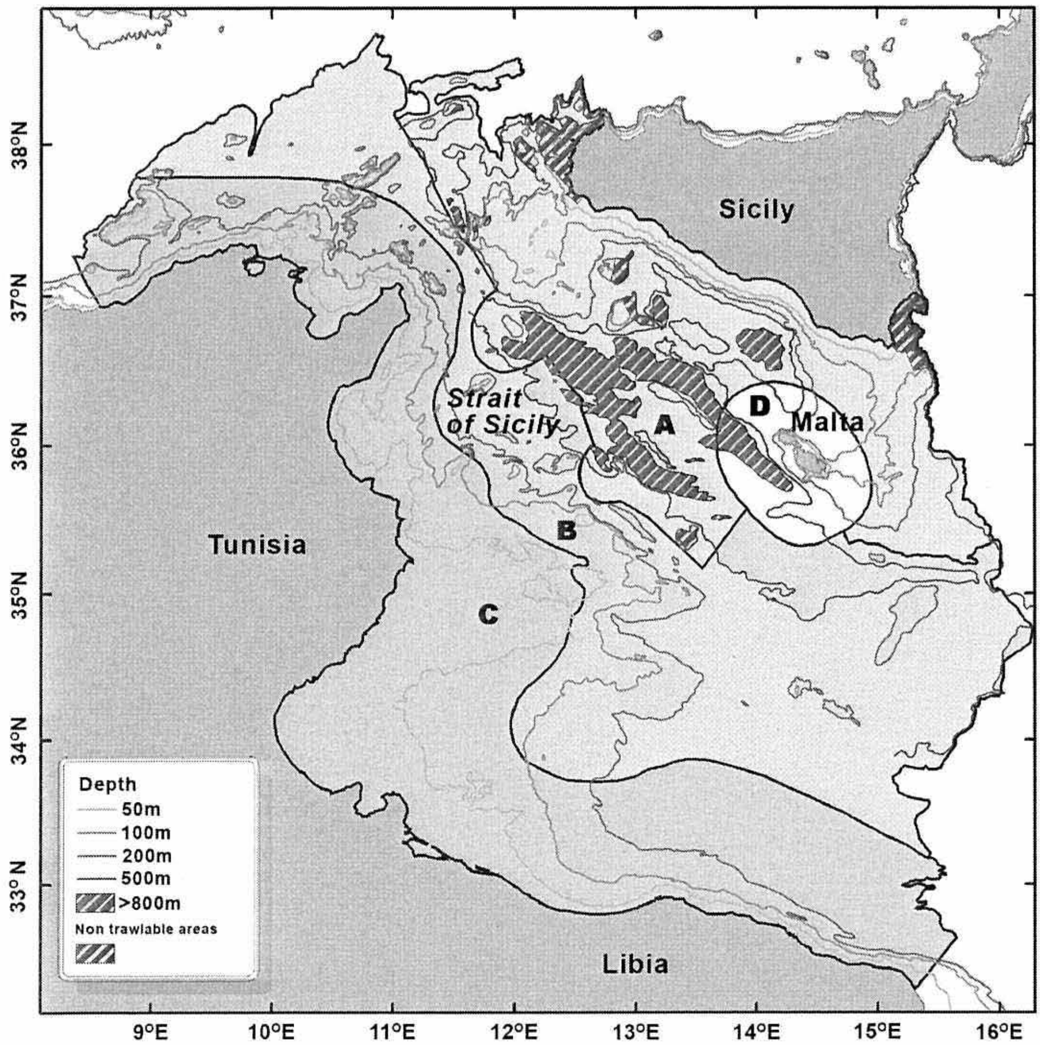

Figure 1.4 The Strait of Sicily with the traditional sub divisions considered by IRMA-CNR. A: Italian side; B: midway; C: North African coasts and D: Maltese Fisheries Management Zone (FMZ).

In 2001, for management purposes the General Fisheries Commission for the Mediterranean (GFCM) proposed new Geographical Sub-Areas (GSA) for the Sicilian channel (Fig 1.8). The two GSAs, the Maltese (GSA 15) and Italian (GSA 16) covered by the Italian and Maltese team were adopted from 2002 onwards, for the MEDITS and GRUND trawl surveys. The GSA 15 includes the FMZ (or D area) and a part of the eastern bottoms of the Strait of Sicily, whereas the GSA 16 covers the western bottoms. According to assessment procedures, most of the demersal resources in these GSAs were found to be "fully exploited" or "overexploited" (except the Maltese FMZ), and a reduction of fishing effort and a change in the fishing pattern were generally recommended in order to ensure the sustainable exploitation of these resources (Levi *et al.* 1998).

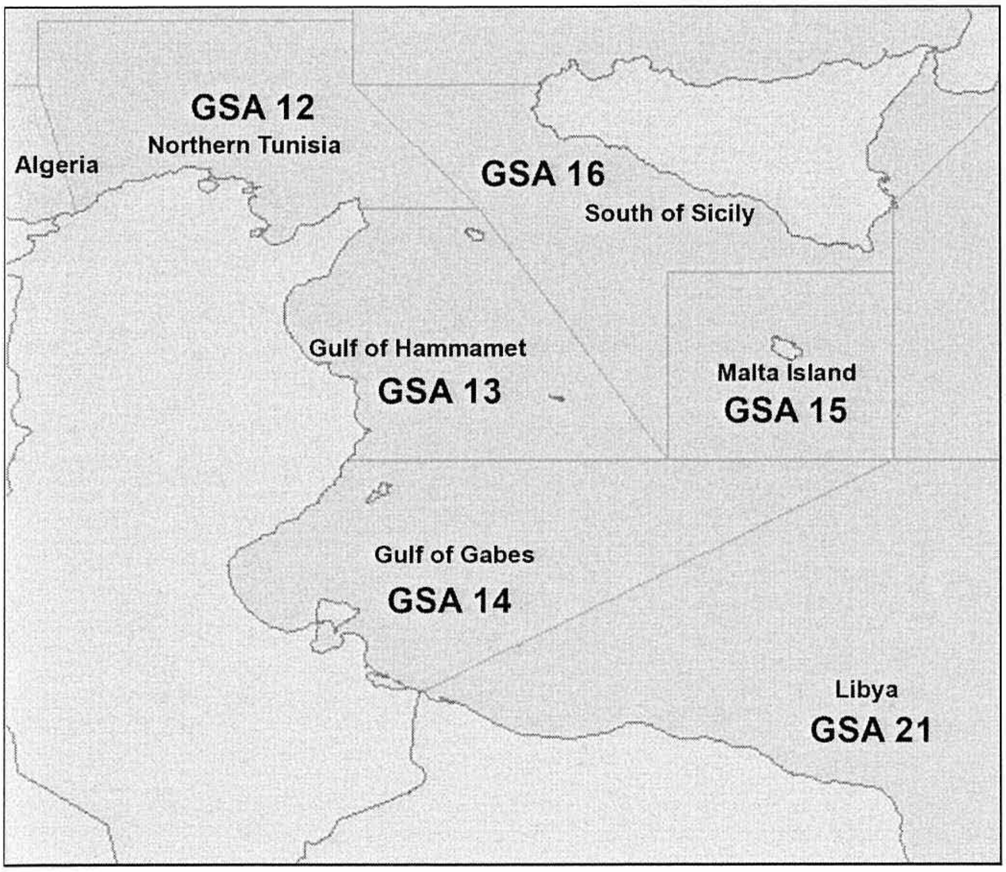

Figure 1.5 The GSA subdivisions of the Strait of Sicily according to GFCM. The GSA 15 and 16 are explored within the GRUND and MEDITS programs; the GSA 21 is only partially showed.

A depth-stratified sampling design which is based on a single sampling phase has been adopted since the beginning and remained unchanged in spite of different attempts to adopt alternative criteria. Unfortunately, depth limits changed slightly according the different cycles. At the moment, five depth (limits in meters) microstrata are defined within both GRUND and MEDITS: 10-50 (Coded with A), 51-100 (B), 101-200 (C), 201-500 (D), and 501-800 (E).

Each microstratum includes both trawlable and not-trawlable bottoms; unknown areas are conventionally considered as "trawlable" till contrary evidences was gathered during the sampling. These represent the basic strata requirements and were codified as "microstratum" to distinguish any other depth reorganisation (macrostrata) which can be proposed; for example, MEDITS present data by shelf (A, B and C) and slope (E and D microstrata).

The sampling stations/hauls (only one haul is normally realised in each station) are randomly allocated within the strata according to an area proportional criterion. To implement the haul extraction, a grid of points (3 nautical miles apart), each representing an Elementary Sampling Unit (ESU), is over imposed to the area and hauls selected by tossing random numbers. The location and expected depth and GPS coordinates of each haul are reported in a clean map and stored (both in electronic format) on board. Generally, the hauls are made in the same position from year to year for MEDITS, whereas a re-selection occurs in GRUND after each cycle (normally 3-5 years).

The overall haul number varies among the years according the available funds; for example, in the MEDITS 2005, 45 were conducted in the GSA 15 (Maltese area) and 120 hauls in the GSA 16 (Sicily area).

1.3 Impact of bottom trawling on the natural environment

Fishing is one of the most widespread anthropogenic activities and research has highlighted the massive impact of demersal towed gears on the marine environment (Jennings and Kaiser, 1998). Bottom trawling has dramatic effects on the ecosystem including physical damage to the seabed, the degradation of associated communities, the over fishing of demersal resources, the changes in the structure and functioning of marine ecosystems derived from the depletion of populations and the huge amount of by-catches and associated discards. Hall (1999) and Kaiser and de Groot (2000) have reviewed a wide range of aspects concerning trawling impacts, including recovery, studies on various fractions of fauna, physicochemical effects, resuspension of fine sediments and nutrients, damage and survival of target and non-target fauna. Experimental and field studies have shown that the abundance of epifauna and infauna (macro- and megafauna) is generally reduced with corresponding changes in community and trophic structure (Dayton *et al.*, 1995; Jennings and Kaiser, 1998; Lindeboom and de Groot, 1998; Collie *et al.*, 2000; Gislason *et* al., 2000; Smith *et* al., 1999; 2000; 2003). However Jennings *et al.* (2001a) could not detect any significant effects on trophic network structure. Bergman and van Santbrink (2000) and Bergmann *et al.* (2001) have demonstrated the mechanical damage to epifaunal and infaunal invertebrates. In a pioneering study, Arntz and Weber (1970) showed that trawl boards crush shells of the long-lived bivalve *Arctica islandica*, and later Witbaard and Klein (1994) found that events of trawl disturbance could be deduced from the occurrence of sand fragments and scars in the shell of this bivalve. However, smaller body-sized fauna, for example, the meiofauna, may be more resistant to trawling (Schratzberger *et al.*, 2002).

1.3.1 The impact of bottom trawling on Mediterranean soft bottoms

The vast majority of the trawled Mediterranean seabed is covered by muddy and sandy bottoms (in some places, rocky) and bottom trawling mainly affects shelf areas covered with such bottoms. In the Mediterranean basin deep water trawl fisheries targeting the Norway lobster or red shrimp also affects slope muddy bottoms. In general, muddy sediments, which form in high depositional areas with low external disturbance, are much more sensitive to trawling disturbance than more dynamic coarser sediments; trawl doors penetrate relatively stable muddy bottoms more deeply than other sediments, with potentially greater effects on infaunal species (Ball *et al.*, 2000).

An otter trawl, which is the most widely used bottom trawling technique in the Mediterranean, has two rectangular otter boards to keep the mouth of the trawl net open and weights attached to the ground rope between the boards to keep the net close to the bottom. The boards may penetrate 15 cm or more into soft mud (Krost *et al.*, 1990) and the tracks may be detectable using sidescan sonar for more than a year after trawling in the western Mediterranean (Palanques *et al.*, 2001). The impacts of the net are probably of shorter duration. Although sedimentary grain size may not change in an area due to trawling (Smith *et al.*, 2000), a number of differential physical impacts can be found over short distances, with heavy plough furrows with associated spoil heaps (door impacts), lightly scraped sediment surfaces (wire impacts), completely flattened and scraped surfaces (ground rope and net impacts), and small patches of relatively untouched sediments (Krost *et al.*, 1990; Smith *et al.*, 2000).

Coggan *et al.*, (2001) give a good review on the methodologies currently present for the quantification of environmental impacts of otter trawls. The marks can be seen with different spatial resolutions and scales by different techniques. Sediment surface impacts can be imaged by side scan sonar over wide areas (e.g. 200 m strips over kilometres) with a resolution of 15–20 cm, allowing only the imaging of door marks (Service and Magorrian, 1997; Friedlander *et al.*, 1999; De Alteris *et al.*, 1999). Video is able to image smaller areas (1–2 m strips over sub-kilometres) with a resolution of approximately 2 cm, allowing the imaging of the majority of trawl marks (Service and Magorrian, 1997; Smith *et al.*, 2000). Sediment profile imagery (SPI) allows the imaging of the topmost sediment layers in profile, including the sediment–water interface. The SPI sampling window gives a relatively small imaged sample in comparison to other imaging techniques (side scan sonar, video, etc.). SPI images can be resolved at the millimetre scale and these include epifauna and flora, infauna, surface features such as burrow openings, mounds and faunal tubes, sub-surface bioturbation traces, gross granulometry (sands, silty clays, shell fragments) biogenically remodelled sediments, sedimentary layers, anoxic sediments, feeding voids and burrow lumens (Rosenberg *et al.*, 2003; Smith *et al.*, 2003).

In the central Mediterranean Italian fleets with hydraulic dredges, otter and 'rapido' trawls (which is similar to a beam trawl) exploits a large trawlable shelf area in the Adriatic Sea and takes shelled molluscs such as the sword razor shell (*Ensis minor*), smooth callista (*Callista chione*), the striped venus (*Chamelea gallina*) and the golden carpet shell (*Paphia aurea*) and flatfish in muddy inshore areas, though it also catches small fish (Ardizzone, 1994; Giovanardi, *et al.*, 1998; Pranovi *et al.*, 2000). The impact of 'rapido' trawls on the sea bottom revealed that it is short-term, digging and furrowing the sediment to a depth of 6 cm (Pranovi *et al.* 2000). Negative effects on the structure of the macrobenthos community were recorded: these included the increase in the abundance and biomass of taxa a week after the perturbation because of the increase in the trophic availability benefiting a few opportunistic scavenger species. Commercial exploitation appears to result in cumulative disturbance as evidenced by the higher biomass of scavenger Crustacea and Echinodermata at the expense of Porifera, Mollusca and Annelida. The authors concluded that, commercial 'rapido' fishing, was selecting epibenthic species most able to cope with physical disturbance by gear and endure the discard process. Experimental studies seem to conclude that "rapido" trawling causes greater short-term disturbance on macrobenthos in muddy areas than in sandy bottoms, although short-lived fauna associated with the former recovers quite rapidly (within two weeks) (Pranovi, *et al.*, 1998). The hydraulic dredge (known in Italian as "cannellara"), which ploughs sediment to a depth of 20-30 cm causes also extensive damage (Relini *et al.*, 1999). The use of hydraulic dredges to catch warty venus (*Venus verrucosa*), a species inhabiting detritic, conchiferous or sandy bottoms and *Posidonia* beds, was banned in Italy in 1992 because of the extensive damage it inflicted. In the south-western Adriatic, the smooth scallop (*Chlamys glabra*) fishery operating on coastal detritic bottoms inside the Gulf of Manfredonia makes big discards, 395 kg from only an hour's dredging, principally of green sea urchins (*Psammechinus microtuberculatus*), molluscs and crustaceans (Vaccarella *et al.*, 1998).

Bottom fishing has deeply affected some Mediterranean invertebrate species, the endemic sponge *Axinella cannabina* or the bryozoan *Hornera lichenoides* (De Ambrosio, 1998). Otter trawling fisheries on muddy bottoms targeting the deep water pink shrimp *Parapenaeus longirostris* destroy the benthic community associated with the seapen *Funiculina quadrangularis*, Anthozoa (Gili *et al.*, 1987; Tudela 2004). Smith *et al.*, 2000 also showed that the epifaunal number, abundance, and biomass, sedimentary organic carbon, chlorophyll, and phaeopigments were all different in trawled areas when compared to control areas. Deep slope fisheries targeting high value crustacean species operate out of Spain, Italy, Algeria and Tunisia, fishing down to a depth of 1000 m depth in the north-western Mediterranean targettig red shrimp (*Aristeus antennatus* and *Aristeomorpha foliacea*). Although there is direct information on the effects of trawling on deep water (400 -1000 m) muddy bottoms in the Mediterranean (or anywhere else in the world), the few authors touching on the subject warn of the extreme vulnerability of such sea beds to physical perturbations. It appears that recovery rates are much slower and the impacts of trawling may be very long lasting (many years or even decades) in deep water, where the fauna is less adaptable to changes in sediment regimes and external disturbances (Jones, 1992; Ball *et al.*, 2000). Otter trawling in red shrimp grounds is injurious to the seapen *Isidella elongata* facies of the bathyal mud biocenosis. This octocorallian species is very much affected by fishing (Sardà, 1997; Tudela, 2004).

The ecosystem effects related to the use of bottom gears may extend far beyond the direct, straightforward impacts discussed above. Eutrophic processes may be enhanced leading to hypoxia in sensitive soft bottom areas (as in the northern Adriatic) and the quantity of hydrogen sulphide released from sediments may increase (Caddy, 2000). The re-suspension of sediment enriched in organic matter can eliminate macrophyte, benthos and demersal fish approaching their hypoxia tolerance limit; the changed ecosystem structure favours species adapted or tolerant to hypoxic conditions. Trawling and dredging can also play a role affecting the intensity and duration of naturally occurring seasonal hypoxic crises in some places. These fishing practices, carried out in hypoxic conditions in the Adriatic, can exacerbate the summer killings of young shellfish. Trawling can also remove large-bodied, long-lived macrobenthic species and subsequently reduce the bioturbation zone (Ball *et al*, 2000). This could increase the danger of eutrophication and result in longer recovery rates (Rumohr *et al.*, 1996). On the other hand, studies carried out on muddy seabeds off the Catalan coast (north-western Mediterranean) showed that otter trawling operations produce short-term changes in the biomass of taxa within the trawled area. Some pointed to simple depletion caused by the gear catch (i.e. the cases of *Scyliorhinnus canicula* and *Merluccius merluccius*) and others to the concentration of scavenging species (i.e. *Arnoglossus laterna*, *Cepola rubescens*, *Squilla mantis*, *Liocarcinus depurator*) attracted by an increased food supply as a result of the mechanical killing of benthic fauna (Demestre *et al.*, 2000b). This typical of scavenger response lasted only about four days. These results suggest that fishing disturbance may cause shifts in the benthic community structure that particularly affect mobile scavenging species, probably the most food-limited group in muddy seabed environments.

1.3.2 By-catch and discards of the Mediterranean bottom trawl industry

1.3.2.1 Quantification of discarding in Mediterranean bottom trawl fisheries

Bottom trawling fisheries in the Mediterranean are essentially multispecies. Information on discards and by-catch in Mediterranean trawl fisheries vary considerably in amount and composition depending on region, boat size, season, bottom type and depth of the exploited ground. In the Maltese islands more than 90% of the total catch in biomass at depths ranging from 50 to 100m deep on maerl beds is discarded (Page, 2003, Dimech and Schembri, 2004, 2005). The discarded biomass is made up of echinoderms (66.5%; mostly *Stylocidaris affinis* and *Centrostephanus longispinus*), followed by crustaceans (27%) and molluscs (5%). Similar high discard levels have been reported for other Mediterranean trawl fisheries, however to varying degrees depending on bottom type. In the western Mediterranean the monitoring of fishing fleets in seven ports (six Spanish and one Italian) gave discard estimations ranging from 23-67% of total catch in bottoms less than 150 m deep, 13-62% in bottoms 150 to 350 m deep and 14-43% in slope bottoms deeper than 350 m (Carbonell, 1997; Carbonell *et al.*, 1998). Data from a single locality, the Catalan port of Vilanova i la Geltru (north-west Mediterranean), illustrate this high quantitative variability. Monitoring of the fleet there revealed that the annual average of discards ranged between 13% and 39% of the total catch for small boats (<

150 hp) and between 17% and 48% for larger boats (> 150 hp), depending on the depths exploited. The amount discarded, however, peaked at 75.4% and 66.6%, respectively, in the case of larger boats operating in spring and smaller ones operating in the summer on shelf bottoms (< 150 m depth). Total annual discards in Sicily during the 1980s were estimated at around 70 000 t, accounting for an average of 44-72% of catches (Charbonnier, 1990). The monitoring of fleets operating in three major Greek fishing grounds (Ionian Sea, Cyclades Islands and Thracian Sea) during 1988-1997 yielded discard estimations of 40%, 55% and 25% of the total catch of fish, crustaceans and cephalopods, respectively (Machias *et al.*, 1999). Field studies carried out in 1995 showed that the fraction discarded by the trawl fleet operating in the Cyclades area, in the Aegean Sea, amounted to 59% of the total catch in bottoms less than 150 m deep, 63% in bottoms 150-200 m deep, and 37% in grounds deeper than 300 m (Vassilopoulou and Papaconstantinou, 1998). On the whole, discards in the Hellenic commercial trawl fishery are estimated to account for 45% of total catch (Stergiou *et al.*, 1998). The 'rapido' beam trawler fleet (56 units) based in Chioggia in the Adriatic Sea produces qualitatively heterogeneous discards depending on the species target (Giovanardi, *et al.*, 1998; Pranovi *et al.*, 2000). Whilst pectinid fishing involves the exploitation of sandy bottoms offshore and discards consist of echinoderms (32% in weight), crustaceans (26%), molluscs (23%) and porifers (15%), flatfish fishing is carried out on muddy coastal areas, where molluscs and crustaceans account for the bulk of discards (60% and 30%, respectively).

High discard levels are also common in the case of Mediterranean deep sea trawling fisheries. Discards by the trawling fleet operating on the upper slope (230-611 m) off Alacante (south-east Spain) have been estimated at 34.6% of the total catch (Soriano and Sánchez-Lizaso, 2000). The low selectivity of trawling is highlighted by data from this fishery showing that up to 95 species are taken; only 12 of these accounts for nearly 89% of the total, and 89 of them are discarded. The analysis of discards in the Norway lobster (*Nephrops norvegicus*) and red shrimp (*Aristeus antennatus*) fisheries at 280-720 m in the Balearic Islands (western Mediterranean), estimated at an average of 42% of the total catch, led the authors to conclude that "an important fraction of the catch of the two deep-sea decapod crustacean fisheries of the Western Mediterranean is discarded"

(Moranta *et al.*, 2000). Longer tows, to compensate for the reduced biomass, seem to result in lower selectivity by the mesh and higher discard rates.

Discarding can also involve important commercial species, especially smallest size classes. Discards of commercial species in Greek waters are reported to range from 0% for red mullet (*Mullus surmuletus*) to 10% for hake (*Merluccius merluccius*) and shrimp *Parapenaeus longirostris* (Machias *et al.*, 1999; 2004). The bulk of discards (66%) in the Balearic deep sea crustacean fisheries at a depth of 300 m referred to above correspond to undersized marketable species. The study of hake discards (*Merluccius merluccius*), forkbeard (*Phycis blenoides*) and poor cod (*Trisopterus minutus capelanus*) in the trawl fishery of the northern Tyrrhenian Sea revealed that they can reach high levels, depending on the species, the season and the depth exploited (Sartor *et al.*, 1999). Maximum estimates of discards were 34.1% of total catch (in weight) for hake, 41% for forkbeard and 39% for poor cod, whereas total annual mean discards in the traditional trawl fishery amounted to 39%, 65% and 57% respectively in numbers of individuals. All individuals fewer than 10 cm are discarded in all three species.

Although a proportion of discards in Mediterranean trawling fisheries may survive, few helpful data on which to base quantitative estimates exist. Observations derived from experiments on aquaria carried out on board point to the low mortality of crustaceans caught as a by-catch in Catalan trawl fisheries, whereas survival rates of fish are highly heterogeneous and vary strongly according to the species (i.e. 0% for *Trachurus* spp. and 100% in *Scyliorhinus canicula*) (Sánchez, 2000). Another study of by-catch survival in the 'rapido' fleet operating in the northern Adriatic showed low mortality in all taxa examined during the three to four hours following capture (Pranovi *et al.*, 1999).

1.3.2.2 Impact of discards on demersal ecosystems

The impact of discards goes far beyond single-species demographic effects, since discarded biomass can alter ecosystem structure by favouring scavengers (Moranta *et al.*, 2000; Demestre *et al.*, 2000b; Olaso *et al.*, 2002). The consequences of the fishingdriven increase in food supply stemming from have seldom been addressed by specific studies.

The only work dealing with this issue in the Mediterranean is based on photographic surveys carried out off the Catalan coast in the north-western Mediterranean, and focuses on the estimation of the consumption rate of fishery discards by scavengers (Bozzano and Sardà, 2002). The study used a baited camera, which was set on the sea floor at a depth of 100 and 300 m in two areas subjected to trawling with continual discards. Eight fish and nine crustacean species were recorded feeding on the baits, and the benthic snake eel *Ophichthus rufus* was the main scavenger species, followed by isopods (i.e. *Cyrolana borealis*) and amphipods (i.e. *Schopelocheirus hopei*). Sporadic scavenging behaviour was even reported for common fish species such as *Spicara* spp. and *Trachurus* spp. Discarded material seems to enter demersal food webs quite quickly, as suggested by the high consumption rates recorded. In all cases baits were fully consumed within 24 hours, and consumption rates reached maximum levels in deep bottoms at night. The authors concluded that the prevalence of *O. rufus* indicated an environment dominated by a monospecific scavenger guild, whose competitors and predators have probably been eliminated by fishing activity. This conclusion is particularly interesting since it highlights the multiple effects of fishing on complex systems such are communities and ecosystems: fishing can favour a single species within the demersal ecosystem by both removing its competitors and independently increasing its food availability through discards.

1.3.3 The impact of fishing on chondrichthyans

International concern over the conservation of shark, ray and chimaera (chondrichthyans) populations has been growing during recent years. This group has been revealed as especially vulnerable to human exploitation, fishing mortality resulting from both direct fisheries as well as high by-catches as a consequence of the use of low selective gears. These species, by nature of their k-selected life history strategies i.e. slow growth and delayed maturation, long reproductive cycles, for example incubation in *Squalus* lasts up to 22 months, low fecundity and long life spans, and their generally high position in trophic food webs, are more likely to be affected by intense fishing activity than most teleosts (Stevens *et al.*, 2000; Castro *et al.*, 1999).

The impact of demersal fishing on Mediterranean elasmobranch populations relates to both direct fishing and the high by-catches due to the low selectivity of fishing practices. Analyses of historical data on experimental surveys and fishery landings have proved useful in detecting clear population declines in some Mediterranean regions. A study based on historical data from both bottom trawl surveys and commercial landing statistics in the Gulf of Lions points to the clear decline of demersal elasmobranch species populations since the 1960s (Aldebert, 1997). The area is exploited by a large trawling fleet (more than 200 vessels, accounting for 2/3 of the total catch) as well as by other small-scale fleets using various gears. Results from experimental trawl surveys indicate that the decline of elasmobranchs started on the continental shelf, and extended recently to the slope. Only 13 of the 25 species recorded in the years 1957-60 were still caught in the period 1994-95, a reduction in the number of chondrichthyan species of about 50%. It is worth noting that decreasing species were mainly fish with some economic value. This is the case of small sharks such as the smooth-hounds *Mustelus mustelus* and *M. asterias*, the smallspotted catshark (*Scyliorhinus stellaris*) and the longnose spurdog (*Squalus blainvillei*), as well as most of the rays. The latter seem to display a special vulnerability to fishing since only two, the starry ray, *Raja asterias*, and the thornback ray, *R. clavata*, of the ten species commercially exploited in the Gulf of Lions were still present in the last surveys; these were the most initially abundant species. Analyses of data on commercial landings led to convergent results i.e. longnosed skate, *Raja oxyrinchus*, a species reaching maturity at a length of 120 cm in the Mediterranean, disappeared from landings as early as 1976.

The evidence for population declines of chondrichthyan species in the North Tyrrhenian Sea is also conspicuous. Historical data series indicate that sharks and rays formed a bigger part of catches in the 1950s than they do today, to the point that some fisheries directed at species then abundant such as the picked dogfish (*Squalus acanthias*) and *M. mustelus* disappeared, as well as some species of Dasyatidae and Rhinobatidae (Serena and Abella, 1999). This declining trend concerning chondrichthyan populations seems not to be exclusive to this region of the NW Mediterranean: similar situations have been reported for the Alboran Sea and the central Mediterranean (Aldebert, 1997; Stevens *et al.*, 2000).

Ray species appear to be especially vulnerable to fishing. In the Northern Tyrrhenian Sea, where an important trawling fleet operates, rays are reported to be among the most important components of the fish assemblages caught by the local beam trawling 'rapido' fleet harvesting in shallow waters. The corresponding catches by the otter trawling fleet are less important (Serena and Abella, 1999). Catches are especially important in the region of Viareggio where high discards of juvenile specimens of the most abundant ray species there, *R. asterias*, not exceeding 28 cm (maturity is reached at a size ranging between 50-60 cm, depending on the sex), are known to occur although the population seems to be stable. As reported in Relini *et al.*, (1999), the most important catches of ray in Italian waters correspond to *R. clavata*, a species abundant in trawling grounds whose juvenile fraction suffers high fishing mortality. Data on this species in the North Tyrrhenian suggest a very high exploitation level. The case of the brown ray (*R. miraletus*) is not very different.

Italian and Spanish demersal fleets discard high levels of juvenile blackmouth catshark (*Galeus melastomus*) and smallspotted catshark (*Scyliorhinus canicula*), species captured with bottom trawl nets at different depths (Relini, *et al.*, 1999; Carbonell *et al.*, 2003). The former is mainly caught as a by-catch in the Norway lobster and red shrimp fisheries. Improved gear selectivity based on an increased mesh size has been suggested as a way of reducing these undesirable catches. In the case of *G. melastomus*, a significant reduction of fishing in the nursery areas may also be necessary, especially in the well-known one located in the Northern Tyrrhenian Sea between Gorgona and Capraia at depths around 200 m. Another species, *S. blainvillei*, was formerly quite common in the Northern Tyrrhenian Sea, whereas at present the population has been considerably reduced because of the high by-catches by the bottom trawl fisheries. As far as other minor species are concerned, *S. acanthias* and *M. mustelus* are captured in Italian waters using traditional bottom nets, as well as longlines and gillnets. The gulper shark (*Centrophorus granulosus*) is caught as a by-catch of traditional bottom trawlnets in slope fisheries.

Chondrichthyan species, mainly involving species of the genera *Raja*, *Scyliorhinus*, *Squalus* and *Oxynotus* also account for the bulk of discards produced by the Greek trawling fleet operating in the Cyclades area in the Aegean Sea (Vassilopoulou and Papaconstantinou, 1998).

Demersal Mediterranean fisheries also impact on large pelagic species such as the great white shark (*Carcharodon carcharias*), a species listed in the Barcelona convention (Annex II) and Bern Convention (Appendix I) and represented by a very low-density population in the Mediterranean. A recent study has shown declines of between 96-99% for pelagic sharks in the Mediterranean (Ferretti *et al.*, 2008). The Sicilian Channel waters, however, are considered as a major area of abundance and reproduction of white sharks within the entire NE Atlantic/Mediterranean region (Fergusson, 1996). This species seem to have been in general decline in Mediterranean waters since 1960. Given the vulnerability of the enclosed Mediterranean population, incidental catches are of special concern. Fergusson *et al.*, (1999) report that large individuals are incidentally entangled in bottom gillnets set close to Filfla Islet and off Marsaloxlokk in Malta, at seabed depths of 15 to 30 m; the same authors refer to white shark catches in similar circumstances in Sicily, Greece and Turkey in recent years. Young - including young of the year - white sharks are also caught elsewhere in the Mediterranean, off Algeria, France and in the North Aegean. The majority of these catches, however, originate from the Sicilian Channel during high summer, being due to trawlers based in Sicily.

1.3.4 Effects of bottom trawling in the Strait of Sicily: a spatial approach

In the last several years the Italian centre for national research stationed in Mazara del Vallo (CNR-IAMC) has attempted to contribute to the study of fishing induced changes in composition, diversity and size spectra of demersal fish communities in the strait of Sicily (Gristina *et al.* 2000; Fiorentino *et al.* 2003; Gristina *et al.* 2003; Gristina *et al.*, 2004; Gristina *et al.*, 2006). The results of the comparisons of the fishing survey in areas exposed to different levels of fishing pressure facilitated the study of the effects of commercial trawl fishing on the demersal fish assemblages (Figure 1.9).

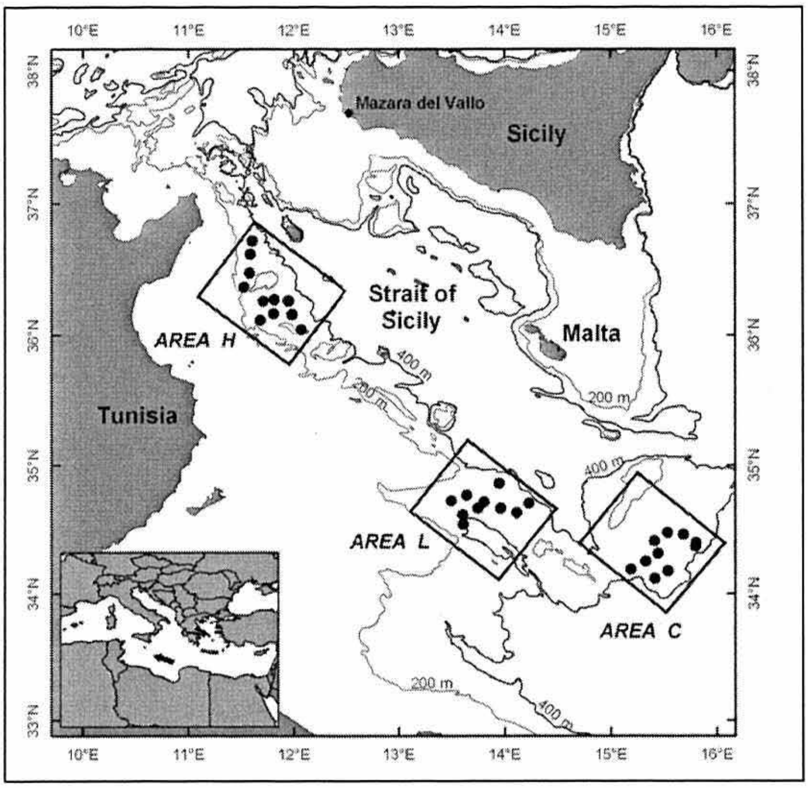

Figure 1.6 Areas with different level of fishing pressure (H high; L low; C control) (from Gristina *et al.* 2006).

According to Gristina *et al.*, 2006 the analysis of the Shannon Weiner diversity index (H`) and the taxonomic distinctness index (Δ) does not seem to be the best way to investigate the impact of the fishing on the demersal fish communities; in fact, significantly lower diversity values are not at all clearly linked to trawl disturbance. On the contrary, the structure of the demersal assemblages and the analysis of the size spectra prove to be more sensitive for detecting changes in the demersal communities. Gristina *et al.*, 2004 developed a multispecies index defined as the ratio between bottom-dwelling fish and overall-fish biomasses (BOI index). According to the authors the BOI index used in association with the representation of the biomass indices, seems to be able to distinguish between areas with different levels of trawling pressure. However the BOI index does not take into consideration the invertebrate benthic communities which are strongly impacted by trawling, especially on the low energy environments in such muddy bottoms (Smith *et al.*, 2000; Smith *et al.*, 2003).

1.3.5 Summary and Conclusions

Bottom trawling gears, namely otter trawls, beam trawls and dredges, have the greatest impact on Mediterranean muddy bottoms and it is clear that bottom trawling should be minimized, given the documented damage they cause to seabed bottoms and benthic communities. The creation of networks of marine reserves totally closed to bottom trawling could help to rebuild degraded benthic communities in adjacent fished areas in the future. Seasonal rotation of fishing grounds through establishing temporal closures could benefit bottoms too since the likelihood of permanent change in bottom communities is proportional to the frequency of gear disturbance, as pointed out by Jones (1992). Ecosystem changes, in any case, should be avoided and the effect of fishing on bottoms and associated communities should be strictly monitored. Bottom trawling in eutrophic areas, prone to anoxia, is a matter of special concern: fishing practices should be significantly limited, at least in the most critical areas and/or seasons. The ecosystem effects of trawling on deep muddy bottoms, i.e. in red shrimp or Norway lobster fisheries, also deserves special attention given the high vulnerability of deep muddy bottom communities to external perturbations.

There is also compelling evidence that discards by Mediterranean unselective trawling fleets are significant. The effect on marine communities is twofold: at a single-species level, the population dynamics of a species are altered, and at the ecosystem level profound changes occur because of the disruption of food webs. Ecosystem modifications are triggered by the change in the biomass and demographic structure of the different species as well as by the increasing food supply for scavenger and opportunistic species. It is worth noting that the latter can result in the trophic connection of separate sub-systems (i.e. pelagic and benthic), making ecosystem consequences even more dramatic.

Although bottom trawling is inherently rather unselective, by-catches and discards can be minimized. Trawling can be limited and technical measures can be introduced to improve selectivity (Campos and Fonseca 2004; Van Marlen *et al.*, 2005). Trawl selectivity within an area depends on many factors, ranging from the depth exploited or the kind of bottom, to the season. Most impacting scenarios could be avoided by restricting trawling both spatially and temporally. In this context, current provisions banning trawling in coastal waters less than 50 m deep or three miles offshore should be enforced effectively. Trawling gears could be made more selective by using higher mesh sizes or incorporating special excluding devices, such as those based on rigid grids. The former solution may be difficult to apply in Mediterranean waters for social and political reasons, but the development and compulsory use of excluding devices increasing selectivity (such as those in use in some North Atlantic waters) deserve attention. Alternatively, the use of a square mesh can also improve selectivity. It is convenient to mention here that shorter trawling hauls are known to reduce discard rates (Stergiou *et al.*, 1998, Moranta *et al.*, 2000).

Partial solutions and technical improvements notwithstanding, the banning of bottom trawling in large marine protected areas throughout the Mediterranean Basin appears to be the only way of maintaining a sample set of demersal ecosystems free of the damage caused by this widespread fishing practice. These areas would moreover be very useful as a basic reference guide to healthy bottom communities in the context of a future ecosystem-based management of Mediterranean fisheries.

Most recent studies show that Mediterranean fisheries are not an exception in the context of the general declining trend showed by elasmobranch populations and their related fisheries around the world. Information on rays and other demersal species deserves special concern, since they have proved to be highly vulnerable to fishing. In this context, the accurate monitoring of catches and the assessment of the impacted populations should be implemented in order to decide how and where to launch measures effective in reducing fishing mortality on target or by-catch chondrichthyan species. Given the usually high trophic level of these species, the conservation of the diversity of this group of important predators (some of them apical), is essential for the health of the ecosystems, as population changes could cascade down with unpredictable effects on many trophic webs. The establishment of marine protected areas in nursery grounds or in areas of special interest, the improvement of the selectivity of bottom trawling in order to reduce by-catches are among the necessary shortest-term measures. Given the role of apex predator played by many elasmobranch species, a systemic management leading to the adequate conservation of the whole ecosystems, including healthy levels of other fish populations, appears to be necessary. Finally, the overall management policy regarding the exploitation of elasmobranch populations, including commercial fisheries, and the related commercialisation processes should perhaps be revised in the light of the latest indicators pointing to the non-sustainability of current practices.

1.4. The Maltese fishing industry

Fisheries in Malta are a relatively small industry where its socio-cultural significance far outweighs its economic importance. The economic contribution of capture fisheries to the national economy is negligible, accounting for approximately €9.3 million. It is in fact a traditional activity which however operates on a small scale, producing small volumes of a very valuable product. The industry is mainly artisanal and fairly typical of the fisheries found in many Mediterranean countries (Leiva *et al.*, 1998). There are no inland fisheries in Malta.

The average value of catches is around 0.10 percent of the Malta's Gross Domestic Product (GDP), with the industry's direct contribution to GDP estimated at around two-thirds of this figure when the cost of imported inputs, particularly fuel, is considered.

The proportion of the working population dependant, to varying extents, on this industry for its livelihood, is around 1.0 per cent. From an international perspective, the value of the annual fish catch in Malta is around 0.07 percent that of the European Union (EU), while total employment, including full-time, part-time and seasonal employment, is around 0.4 percent of the EU total in the sector.

In 2006 the Maltese fishing population consisted of about 2,378 registered fishing vessels of which 19.6 % are based in the picturesque fishing village of Marsaxlokk while 14.9% are based in the island of Gozo. Out of these 2,378 vessels only 57 are considered as industrial vessels (i.e. over 15 m in length). These industrial vessels are trawlers, longliners and netters. All the vessels except the bottom otterboard trawlers are considered as multipurpose since they undertake all types of fishing with changes of gear from one season to the next. The remaining 2,321 boats are owned by full-time, part-time and recreational fishermen. They differ substantially in shape, size, gear utilised and hours spent in fishing activities. Both professional and sport amateur fishermen fish in coastal and offshore waters.

In 2006, there were 422 vessels registered as professional commercial full-time (MFA), 990 registered as commercial part-time vessels (MFB) and 966 vessels were registered as recreational or sport fishing vessels (MFC). Full-time is the term used for fishermen whose main income is derived solely from fishing. Most fishing vessel owners own more than one vessel. It must be pointed out that fishing in Malta is mainly seasonal and as a consequence some of the fulltime fishermen own at least one small and one large vessel which enable them to practice off-shore fishing during the milder seasons and coastal or coastal activities during the winter months. The average number of fishermen employed on each fulltime boat is around three persons per unit during winter, whilst when undertaking trips of more than two days, extra hands are sometimes recruited for the tuna and lampuki seasons.

1.4.1 Fishing Vessels

The Maltese fishing fleet is composed of two distinct types of vessels which may be categorised as modern and traditional (Fig. 1.10). The traditional boats are the 'Luzzu' and 'Kajjik' which are distinct from modern fishing vessels both in shape, size and range of fishing activities. The 'luzzu' is the foremost traditional fishing vessel. It is pointed at both ends and is painted in characteristic bright colours. (Before the introduction of modern registration of each vessel the colour of the bow used to indicate the home port of each particular boat). The average overall length is 6.7 m and the hull material is wood. These vessels have been the mainstay of the fleet in times gone by and their average age is 37 years old. The average GRT is 2.3, and the average power is 30 kW. The 'Kajjik' differs from the luzzu in being generally smaller (average length 4.6 m) and being flat at the stern. Previously, they were made of wood, but in recent years glass fibre polymer has been the material of choice, with the consequence that at present, with the average age being 19 years, there are marginally more glass fibre polymer "kajjiki" than wooden ones. With an average GRT of 1, the average power is only 17 kW. The 'kajjik' is the most prevalent vessel, there being two and a half times as many as there are 'luzzijiet'. Following the 'Luzzu' and 'Kajjik' the Multi-Purpose Vessel (MPV) is the most common. The MPV's have an average overall length of 8 m. These vessels are a relatively recent addition to the fleet, and the average age is eighteen years. This is also reflected in the hull material, with the majority being made of glass fibre polymer whilst the remainder are constructed of wooden planking, and to a lesser degree marine plywood. They are normally referred to as 'bimbu' and/or 'lancia'. The average GRT is 4.6 and the average power is 78 kW.

Generally the modern fishing boats operate on the high seas for swordfish, tuna and large demersal species whilst the 'Luzzu' and 'Kajjik' are used more for coastal artisanal fishing which includes small long-lines, trammel netting and traps. There are only a limited number of trawlers, most of which are less than 24 m in length and all use a "Mazzara" type of trawl net and gear.

MPV 'Luzzu' 'Kajjik'

Figure 1.7 Modern and Traditional Maltese fishing vessels.

1.4.2 Fish Markets

The larger part of landings originates from international waters. The main landing sites in Malta are Marsaxlokk Harbour, the wholesale fish market in Valletta, and Marfa. Whilst Mgarr Harbour is the main landing site in Gozo. Most of the catches caught by local fishermen is sold through the Wholesale Fish market in Valletta. Catches are sold by public auction through a middleman to retailers and fish hawkers. All dealers in fisheries products are registered with the Veterinary Affairs and Fisheries Division (VAFD). Statistical data for landings is collected through logbooks a catch assessment survey for the small scale fishery and the daily returns of sales submitted by middlemen at the Wholesale Fish market in Valletta. However this only covers sales effected in Malta since there is no organised market in Gozo. Sales in Gozo and direct sales by fishers in Malta are recorded through fiscal receipts and logbook data. Changes in the fishing regulation system such as the minimum thresholds of catches for various classes of vessels adopted in 2004 and the improved surveillance of fisheries activities by maritime patrols have improved the registration of landings.

The fish bought wholesale, is marketed by 250 registered fish vendors on carts, vans, or through shops each of which has his own particular zone where to dispose of his wares. The number of modern fish shops is sprouting all over the island. These are all finished up to the latest sanitary standards and guarantee that the public obtain fresh fish in the best possible state. Most of these fish shops are also increasing the marketing of frozen fish from Europe and imported from other countries.

Due to the ever-increasing demand for fish from locals and tourists, another important outlet for disposing of fish is the catering industry which is increasing the preparation of different specialised fish dishes which appeal to different international tastes.

1.4.3 Landings

Landings from marine capture fisheries are dominated by dolphinfish "lampuki" (*Coryphaena hippurus*), blufin tuna (*Thunnus thynnus)*, and swordfish (*Xiphias gladius*) in decreasing order of importance. Over 65 percent of the annual landings (about 1,000 tonnes) originate from the tuna and dolphinfish fisheries and contribute to almost 56 percent of the value of annual landings (about €2.6 million). The actual percentage attributed to any one of these three species depends on the actual volume of landings and market price for each particular species in a given period. The price of lampuki and swordfish varies enormously and the percentage importance attributed to them will therefore change in different time periods.

1.4.4 Type of Fisheries in the Maltese Islands

The most important fisheries in Maltese waters are those for bluefin tuna, dolphinfish, swordfish, demersal and small pelagics. These fisheries are operated on a seasonal basis, according to the particular targeted species' migratory or biological behaviour (Table 1.2).

Table1.2 Seasonal pattern of fishing activity in the Maltese islands

Fishery	Period	Location	Fishing Gear	Species
Tuna fishery	April – June	Offshore	Drifting Surface Longline	Bluefin Tuna, Swordfish
Trawl fishery	All year	FMZ Offshore	Bottom Otter Board Trawl Nets	Red Shrimp, White Shrimps, Red Mullet, Hake
Demersal fishery	January – July	FMZ Offshore	Bottom Set Longlines	Wreck fish Bream
Small Pelagic fishery	March – August	FMZ	Lampara/Purseseine, Cane Pots	Bogue, Mackerel
FAD fishery	August – December	FMZ Offshore	FADs and Surrounding Nets	Lampuki, Pilot fish, Amberjack
Swordfish fishery	All year	FMZ Offshore	Drifting Longlines	Swordfish, Spearfish, Lampuki

1.4.4.1 Bluefin tuna

Bluefin tuna (*Thunnus tynnus*) has been fished by Maltese fishermen for a very long time. Originally this species was targeted by fixed traps. Since 1980 the main gear in this fishery has become surface drifting longlines. Tuna is targeted by Multi-Purpose Vessels ranging from 10 meters upwards involving around 87 full-time commercial vessels. The drifting surface longline is baited with Atlantic mackerel and/or Japanese squid. The maximum number of hooks set in a longline is 2,500 but this also depends mostly on the size of the boat. The main line is usually monofilament with a diameter ranging between 1.8 – 2.0 mm. Along the main line, there are the side lines/snoods which are about 6 m long. The snoods are also made of monofilament but with a smaller diameter of around 1.6 mm. The snoods are laid at 54 m intervals. The hooks used are of the Japanese round type. Fishing is undertaken about 30 – 50 nautical miles from the West, South and South East of the Island. The lines are set outwards and therefore fishing takes place in an area which covers approximately 2,000 sq. miles. At the beginning of the season, April, the effort is undertaken mainly in the West area of the region and consequently further to the South West, South and South East according to the normal migration of the bluefin tuna. These vessels are awarded annual licences commencing on the 15 April of each year. Since 2003 a pilot purse seine fishery has also been involved. The season ends at the end of June.

1.4.4.2 Dolphin fish

The dolphinfish (*Coryhaena hippurus*) or 'lampuka' in Maltese is one of the most important species for the economy of the Maltese fishing industry. In fact up to a few years ago it was actually the most important fishery due to its appeal to the public and the abundance of catches which regularly occur each year. Due to its traditional appeal a consistent number of boat owners participate in this seasonal activity. The authorities have been involved in the management of this fishery in the last 100 years. Lampuki are captured using 'fish aggregating devices' (FAD's). These FAD's are small rafts made of floating material, which are then anchored to the bottom. They were introduced after it was noticed that lampuki along with other species such as the pilot fish (*Naucrates ductor*) and the amberjack (*Seriola dumerilii*) tend to aggregate within the canopy of shadow that these floats make. To further augment the number of fish, palm fronds are attached underneath each float. Once the lampuki are aggregated, they are caught by surrounding nets without a purse-line. When the boat is near an FAD various trolls made out of feathers or artificial bait are set and one fish is caught, a decoy dolphinfish is thrown into the sea to attract any others that may be present under the FAD. When the number of fish present makes it worthwhile, the surrounding operation is then undertaken. A variation to this original day fishery is the surrounding of the FAD's at night with the use of a strong search light to keep the fish aggregated during the surrounding operation.

1.4.4.3 Swordfish

Swordfish (*Xiphias gladius*) is targeted throughout the year although in varying degrees. The peak period is from late June to August when other boats revert from tuna to swordfish fishing prior to starting operations for dolphinfish from September onwards. Only about 10 MPVs are equipped solely with swordfish longlines, the rest adapting their gear according to different seasonal fisheries such as swordfish, tuna and lampuki. During the peak period 140 boats may actually target swordfish and this involves between 200 and 250 fishermen. The only gear used for swordfish is surface drifting longlines and the number of baited hooks varies according to the boat's size and range. The larger boats which venture beyond 25 miles and remain at sea for at least 5 days may set as many as 2,000 hooks at any time, weather permitting, whilst the smaller craft spend a maximum of 3 days at sea and set between 500 and 700 hooks per haul. The fishing technique is identical to that used for tuna but the characteristics of the longline are different. The bait is exclusively Atlantic mackerel and the size of each mackerel varies according to the period when different sizes of fish are targeted.

1.4.4.4 Demersal Fish

Fishing for Demersal species is undertaken with different types of gears: gillnets and entangling nets, bottom trawlers, bottom longlines and traps. Different types of bottom gillnet and entangling nets are used in the Maltese Islands. These are a) trammel net locally known as 'Parit'; b) the 'Xkitt' which is a gillnet; c) 'Xkatlar', a single mesh bottom gillnet. They are mainly used during the winter months when the weather does not allow long term fishing on the high seas but their use is extended over the whole year. These gears are used both by day and night depending on the particular species being targeted, e.g. demersal species late evening and night, pelagic species during the day. The product is commercialized fresh and is for local consumption. The main fishing area is along the coast, at 10-40 m. depth. These activities are undertaken by a large amount of vessels of the smaller categories, such as 'Luzzijiet', 'Kajjiki' and MPVs which are less than 12 m in length. These boats are usually manned by 1 or 2 fishermen. The 2 largest vessels lay around 2.5 km of nets whereas all the others normally lay less than 1 km per vessel.

Bottom longlining targets several species of Bream (Sparidae spp.), dentex (*Dentex dentex*), wreckfish (*Polyprion americanus*), groupers (*Epinephelus* spp.) and common red porgy (*Pagrus pagrus*). Usually these longlines are set in deep rocky areas near the slope, at depths of 200 m to 700 m. Different demersal set longlines are used in Malta, which target species of different sizes. The variations occur in the main line and the size of hooks. Vessels are usually bigger than 10 m in length and approximately 30 vessels are engaged in this fishery with about 90 fishermen. In view of the reluctance on the part of fishermen to impart positions of good fishing grounds no exact zoning of these activities can be achieved, and the approximate areas of this fishery are disclosed by the fishermen as a sign of good will from their end.

1.4.4.5 Pots and Traps

Traps are used to catch a wide range of demersal species and are constructed in different shapes and sizes according to the species being targeted. The material used to construct these traps also varies according to species. For species such as moray eel (*Muraena helena*) and octopus (*Octopus vulgaris*) the material used is chicken wire netting, whilst for bogue (*Boops boops*), picarel (*Spicara* spp.) and similar species the material used is cane cut into fine strips or special reeds. Shapes vary according to the habitats of the targeted species, meaning that for demersal species the shape would be rectangular, whilst bell or pear shaped traps are used for mid-water species. Approximately there are 180-200 vessels using traps. These vessels are normally the 'kajjik' and small 'luzzu' type, with lengths under 10 m. The number of fishermen per boat varies from 1 to 2 fishers. The product is always consumed locally and sold as fresh fish.

1.4.4.6 Small Pelagics

Coastal pelagic fishing in the Maltese Islands has been practised for a very long time and at least from 1930 when 'lampara' fishing was first introduced locally and up to a few years ago it was very important part of the total national fishing effort when landings of chub mackerel (*Scomber japonicus*), Atlantic mackerel (*Scomber scombrus*), horse mackerel (*Trachurus trachurus*), bogue (*Boops boops*), allice shad (*Alosa alosa*), sardines (*Sardina pilchardus*) and anchovy (*Engraulis encrasicholus*) were quite abundant and in fact use to constitute 30% of the total fish landings, but since the 60's the effort became minimal and catches are now insignificant. The main importance of sardines and anchovy in particular was because they were bought by fishermen to use as bait. Also, before the advent of large scale targeting of swordfish and tuna and the introduction of demersal species such as hake and red mullet on a large scale, the local market use to absorb all the catches, especially chub mackerel, which was then, along with the dolphinfish, one of the most sought after species.

At present only nine purse seiners based in Marsaxlokk (Malta) and Mgarr (Gozo) undertake this fishery with the main targeted species being the chub mackerel which is still marketable to a certain degree. The term 'lampara' is used because fishermen use strong lights to attract fish, which are then caught by purse seining. The boats used for this fishery are in the 10-15 m length category. The purse seine is between 400 to 450 m long and about 105 m high. Fishing takes place all along the North side of the island but the main zone is around a shallow area covering about 5 square miles, known as Hurd bank to the South East. The depth is between 45 and 55 m with the intermediate area descending to a maximum of 100 m. 'Lampara' fishing is undertaken throughout the year except for the period from September to December when these boats target the lampuki.

1.4.4.7 Bottom trawling

There are only sixteen licensed bottom otterboard trawlers in Malta involving about 80 seamen. They operate in areas within the 25 nautical mile limit, and outside depending on their size and engine power. Trawling is undertaken both during the day or night for purely operational reasons. Due to the complexity of the local market trawling is also seasonal, in the sense that certain species fetch good prices at particular periods of the year. In actual fact, three different types of trawling activities are undertaken during the year:

a) Deep sea trawling (during the day) in 600 m and over, where red shrimps (*Aristeomorpha foliacea* and *Aristeus antennatus*) are targeted. When fishing red shrimps there are low quantities of discards, except for small marketable by-catches of forkbeard (*Phycis blennoides*) and hake (*Merluccius merluccius*). Red shrimps are found in depths of over 500 meters throughout the year at all hours of the day since daylight does not penetrate that depth. The trawling grounds are found in an area about eight miles to the North West of Malta. Since the terrain is composed of mud, and free from obstacles, the duration of each trawl is at least 4 hours, consequently advantage is taken of the long daylight in the summer as at least 3 trawls a day can be undertaken. Vessels with small engines cannot trawl at these depths.

b) Trawling in depths of between 150-200 m, (during the day) where the terrain is mainly mud and clay yields pink shrimps (*Parapenaeus longirostris*), hake (*Merluccius merluccius*), squid (*Illex coindetti*), cuttlefish (*Sepia officinalis*) and marketable by-catches of dogfish (*Squalus* spp.) spotted dogfish (*Mustelus* spp.), skates and rays (*Raja* spp.), bogue (*Boops boops*) and mackarel (*Trachurus* spp.). These species are fished very close to land (3/4 miles) and the activity is mainly carried out in winter, when the weather does not allow to fish in deeper waters.

c) Trawling at night in depths of between 50 and 150 meters where the bottom is hard and rocky, yields red mullet (*Mullus barbatus*), octopus (*Octopus vulgaris*), comber (*Serranus cabrilla*), Pandora (*Pagellus* spp.), squid (*Illex coindetti*), cuttlefish (*Sepia* spp.) and weaver (*Trachinus* spp.). This type of trawling is undertaken all along the Northern side of the island but the main zone is on and around Hurd Bank where stocks are more abundant. Trawl time can never be longer than one hour, since the rough terrain will put too much strain on the trawl nets and damage them. This allows for several trawls to be carried out during the dark hours. This trawling is restricted to vessels under 24 meters and engine power below 185 kW.

In all cases the nets used are the Mazzara type otter trawls which are adjusted according to the type of terrain in which operations are being conducted.

1.5. The Maltese Fisheries Management Zone (FMZ)

Previous to becoming a member of the European Union, Malta had an Exclusive Fishing Zone that extended to 25 nautical miles from the baselines of the Maltese Islands. With entry of Malta into the European Union, this zone was maintained as a Fisheries Management Zone (FMZ) around the Maltese Islands – the first of its kind in the Mediterranean (Fig 1.11). This FMZ is included within the GFCM Geographical sub-area 15, which has an overall area of some 23,600 km^2.

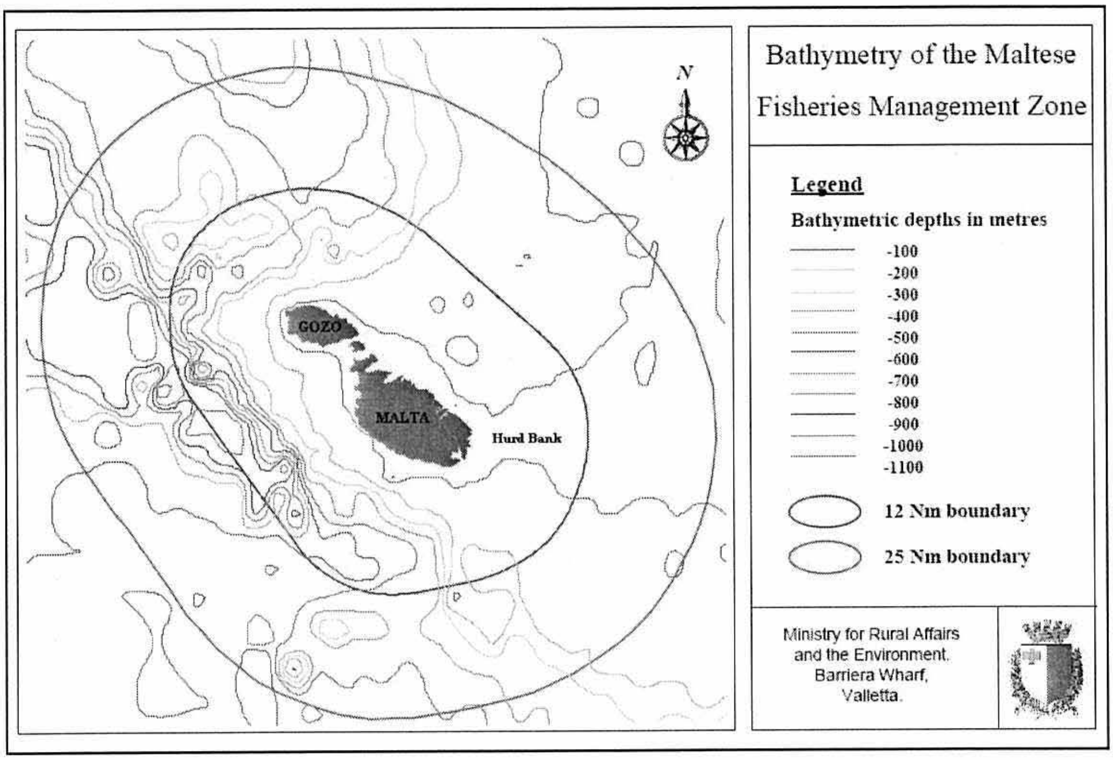

Figure 1.8 Map of the Maltese islands with bathymetric depths in m showing the 12 and 25 NM limits.

1.5.1 Establishment of the FMZ

Malta has managed an extended fisheries management zone, beyond its territorial waters, since 1971 and has maintained a strict licensing scheme, keeping large scale industrial fishing such as trawling at a minimum. From the start of negotiations with the European Union, Malta stated that as a member of the EU, Maltese fisheries should be safeguarded and resources within the current 25 mile Exclusive Fishing Zone (EFZ) should continue to be kept at sustainable levels. Concern was expressed on the inevitably large increase in fishing intensity that would occur in the zone if it were to deregulate the band between 12 and 25 nautical miles which would become Community Waters. Malta had proposed that in line with the "Code of Conduct for Responsible Fisheries" of the Food and Agriculture Organisation (FAO) of the United Nations, a precautionary approach had to be adopted and a tight control on the increase in fishing effort should continue to be kept especially with regards to demersal trawl fisheries.

Using the available data the Maltese government demonstrated that there were criteria for defining the area as a distinct conservation zone (MEDITS 2000; Anon., 2001). Amongst the sources of evidence to establish the conservation zone, MEDITS trawl survey data were used. Fish abundance data obtained from trawl surveys from Maltese waters were compared with those of Sicilian waters and revealed that, in general, the abundance or catch rate at depths between 50 and 500 meters was double in the former zone (MEDITS 2000; Anon., 2001). There was also evidence that adult populations of shallow (less than 200m depth) shelf resources within the zone were isolated from adjacent areas and that the Maltese shelf constitutes the main offshore area where spawning could take place for a significant proportion of the zone's demersal resources and other deep water species zone (MEDITS 2000; Anon., 2001).

Moreover as a consequence of the oceanographic features in the region, larval contribution from outside the Zone was an unlikely source of major recruitment of juvenile fish to demersal fisheries (Camilleri, 2003; Drago, 2003). In addition, satellite imagery also showed clear evidence that Malta was surrounded by water masses which are limited in productivity (oligotrophic), making the ecosystem within the zone more prone to negative effects caused by high exploitation rates (Camilleri, 2003; Drago, 2003).

One of the main management tools in the FMZ is through the limitation of fishing effort, such as the limitation on the number of boats, their horsepower and fishing capacity. The EU was informed that Malta had taken such effort control measures on a routine basis and from the best available scientific information, the demersal fisheries resources within the 25 mile zone appeared to be close to Maximum Sustainable Yield

(MSY) conditions and that they would be placed in a seriously over fished condition, if the fishing effort would be increased even by just adding a few large trawlers (Camilleri, 2003).

The fisheries management regime could also possibly allow escapement of demersal species into non-exploited or slightly exploited areas creating important refugia for spawners and juvenile fish from which the latter eventually recruit them into fishing areas both within and outside the zone. In this respect, it was therefore stressed that areas where trawling is currently absent should continue to remain free from this type of fishing operation, both to maintain these vital sources of recruitment and also to protect fragile benthic ecosystems which are likely to be present in these particular areas. Besides, focussing on demersal resources, negotiations dealt with highly migratory fish species such as the dolphin fish, tuna and swordfish, which make up more than 70 percent of the value of Maltese total annual landings (Agriculture and Fisheries statistics 1998-2004). In this context, it was stressed that the sustainability of fisheries for these species in ecological, biological, economical and social terms should be safeguarded.

The Maltese fishing industry is economically, geographically and culturally dependent on artisanal fisheries (Leiva *et al.*, 1998), and that the introduction of large scale industrial practices would completely disrupt artisanal fishing operations. With particular reference to the vulnerable blue-fin tuna Mediterranean stock, Malta proposed that the Principal of relative stability should be applied whereby the fishing effort on this stock in recent years would not change both in intensity and spatial distribution. By increasing the fishing effort, especially by using large scale industrial fishing gears, would not only contribute to a reduction in the abundance of tuna stocks but could also affect other species such as mammals and birds.

1.5.2 Current Management Regimes

The measures adopted for the management of resources within the 25 Nautical Mile Fisheries Management Zone essentially limit fishing effort and capacity by restricting size and engine power. In particular, only vessels smaller than 12 m are allowed to practice fishing in the zone since these are considered as boats which practice small scale coastal fishing and which therefore have minimal impacts on the marine environment. This means that for a boat from any other country to fish in Malta's 25-mile zone it would have to be smaller than 12 metres. But it is known that it is not financially feasible for boats of this size to do so because of the fuel costs incurred in covering the distance. Certain EU countries also have national laws that ban boats that are smaller than 12 m from leaving their coastal waters. All these factors make it very difficult for foreign boats to operate in Malta's 25-mile zone. The number of vessels that can fish in this zone has been set by the Treaty of Accession and is reflected in Council Regulation (EC) 813/2004 and Council Regulation (EC) 1967/2006.

Equally, however, since the agreed measures do not discriminate between Maltese and EU fishermen, the outcome of negotiations also means that as a rule, Maltese fisherman who own boats that are larger than 12 m and fish in the 25-mile zone will not be able to continue doing so in the same way. This category of fishermen is made up of less than 50 boats. But these were assisted by the Maltese Government to be able to fish outside the zone by gaving financial aid to allow them to upgrade their equipment to enhance their fishing efficiency and be able to fish outside the zone. This aid was given over a period of 18 months and focused on improving the efficiency of the boat as well as bringing the fishing boats in line with new health and safety requirements.

By way of exception to the above arrangement, four types of fishing activities nevertheless are allowed in Malta's 25-mile zone by vessels that may be larger than 12 m. These fishing activities were still allowed to fish inside the zone due to the historial fishing activity of these vessels since 1971. These fishing activities are the following:

a) Trawling

Trawling in designated areas within the conservation area is allowed, although the total trawling capacity within the 25-mile zone should not be more than 4,800 kW. The size limitation of trawlers has been set at 24 m. This means that only trawlers smaller than 24 m will be allowed to trawl in the conservation area and within this area trawling will be limited to specified areas within the Zone (Fig. 1.12) so as to conserve existing 'refugia' and fragile benthic ecosystems. As a further restriction, in areas where the depth of the sea floor is less than 200 m, such as the Hurd Bank, apart from being smaller than 24 m, trawlers must also have an engine capacity that does not exceed 185 kW. Again, there can be no further registration of otter bottom trawlers that can fish in the zone.

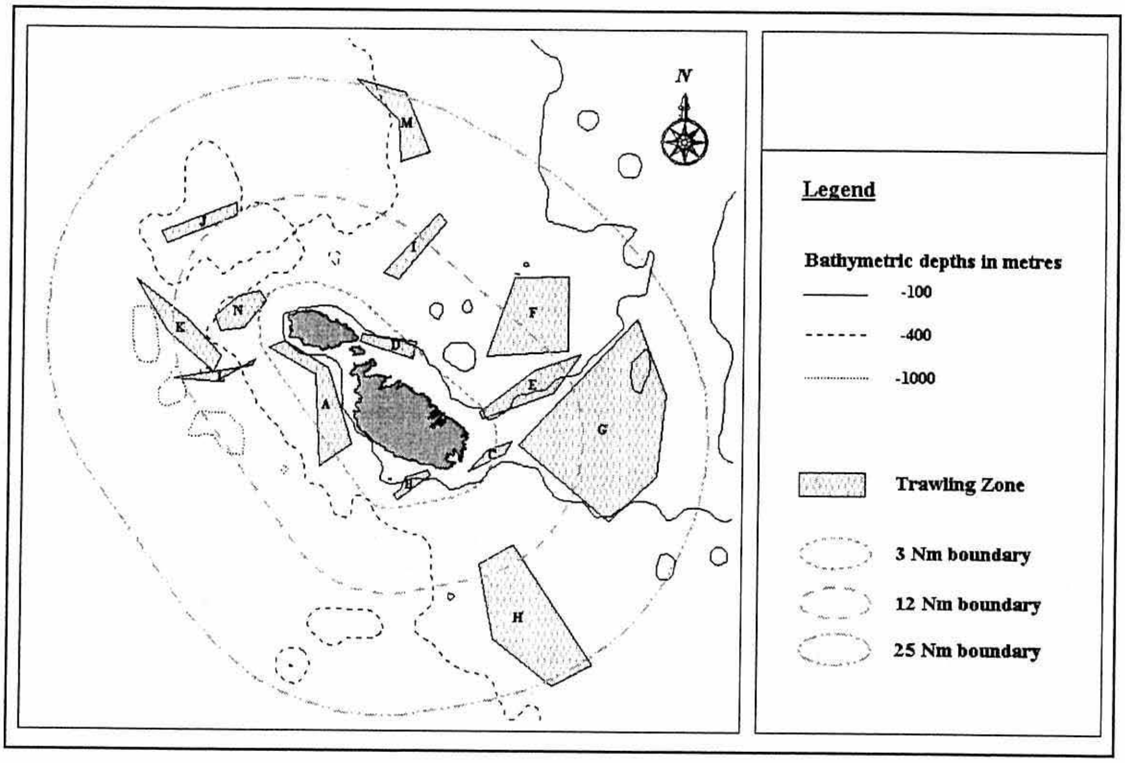

Figure 1.9 Map of the Maltese islands showing the trawlable areas.

b) Fishing for dolphinfish

The management regime adopted through the years by the Maltese Authorities addresses the dolphinfish (*Corphaena hippurus*) fishery since fishing operations start within the Fisheries Management Zone (usually starting at 7 miles from the coastline). In Malta, the government issues permits for Fish Aggregating Devices (FADs) which are laid in the sea along straight-line course. There are 130 possible locations where these courses may be placed around the Maltese Islands. In recent years, Maltese fishermen have taken up around 110 of these courses each year. Any reminder will be available to any EU fishermen who may wish to apply for a permit to fish for dolphinfish. There is no size restriction on the vessels fishing for dolphinfish. This means that a boat which is larger than 12 m can fish for dolphinfish during the season. Only Maltese registered vessels will be allowed to fish for dolphinfish in the waters closer than 12 miles from the Maltese shores.

c) 'Lampara'

There are no restrictions on lampara fishing. This is small pelagic purse seining which means fishing with a net that closes up around schools of fish such as bogue (*Boops boops*) and mackerel (*Trachurus* spp.) aggregating the fish with the aid of light. This type of fishing is dying out and there are very few fishermen who still practice it in Malta, partly due to the stocks not being consistently present and due to the low marketability and value of the catches.

d) Fishing for tuna, swordfish and other highly migratory fish

Migratory fish do not fall into the remit of the conservation area as by their very nature, being migratory, they are not a resource of the area itself. Management of the bluefin tuna fishery that is normally carried out off shore entails the issue of special licences. A basic set of vessels holding the goodwill for these longline licences exists but from year to year licences of vessels that would not be operating in a certain year will be awarded to other vessels for that year. A close watch on landings of this species is maintained and totals for landings are calculated at the end of each week to allow the competent authority to effect closure of the fishery when the Total Allowable Catch (TAC) is achieved. In most years the longliners did not manage to land the quota due to gear conflict with purse seiners and interference by tuna cage towing vessels. During the last 4 weeks of the season the two tuna purse seiners in the fleet were allowed to fish when the landings of the longliners do not amount to more than 60% of the quota. This special management scheme for bluefin tuna ensures that the allocation is utilized and that no over fishing takes place.

Figure 1.13 shows a summary of the agreement reached with the effort of negotiations with the EU. Efficient monitoring and control of the activities of vessels within the Zone is supported by an electronic Vessel Monitoring System. Vessels over 24 meters in length along with those vessels over 12 meters in length which are authorised to carry out fishing operations within the Zone are obliged to carry the required tracking electronic equipment on board at all time.

AGREEMENT ON THE MALTA`S 25-NMILE FISHING		
IN THE 12 MILES	12 TO 25-MILE ZONE	OUTSIDE 25 MILES
⇩	⇩	⇩
Today		
Only Maltese fishermen	Only Maltese fishermen	Maltese fishermen can fish in international waters
Witout negotiations		
Only Maltese fishermen	Maltese and EU fisherman	Maltese fishermen can fish in: • International waters • EU waters • Waters of non-EU countries which conclude a fisheries agreement with the EU
As a result of negotiations		
Only Maltese fishermen	Only fishermen who hold a licence today. No new licences will be issued. Amount of fishing cannot increase.	Maltese fishermen can fish in: • International waters • EU waters • Waters of non-EU countries which conclude a fisheries agreement with the EU
⇧	⇧	⇧
IN THE 12 MILES	12 TO 25-MILE ZONE	OUTSIDE 25 MILES

Figure 1.10 Summary of the agreement reached on the 25 NM FMZ.

The management regime for this unique Mediterranean Fisheries Management Zone (FMZ) has answered in some ways to the international call to adopt an ecosystem approach to fisheries (Camilleri, 2003). In fact, the foundation criteria for defining the FMZ include aspects of productivity, oceanography and physical characteristics in the region. It also covers the conservation of various levels of the fisheries resources in the food chain together with fragile benthic ecosystems, and protects species such as mammals and birds by restricting the type of gear used in the Zone. Ultimately, the ecological, biological, economical and social environments which, to a certain extent, makeup the fisheries ecosystem have been safeguarded and the sustainability of fisheries within the 25 nautical mile Fisheries Management Zone has been guaranteed.

Chapter 2

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

This chapter was a preliminary study to determine the suitability of the different variables and data sets investigated, for further analysis and it was essential for the studies that followed. However the study was still published as a paper in the Maltese scientific journal Xjenza as:

Dimech, M., Camilleri, M., Gristina, M., Kaiser, M., Schembri P. J., (2005). Commercial and non-target species of deep-water trawled muddy habitats on the Maltese continental shelf. *Xjenza* 2005; p. 18-23

2.1 Abstract

Prior to joining the European Union, Malta operated a 25nm Exclusive Fishing Zone that was retained as a Fisheries Management Zone (FMZ) following EU membership. The present study was conducted in this FMZ 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.

2.2 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 2.1). Post-EU membership, this zone was retained as a Fisheries Management Zone (FMZ). The Maltese FMZ, which covers an area of 11,980 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. In general the MEDITS programme is conducted by all the Mediterranean European Union states and was designed to contribute to the characterization of bottom fisheries resources in the Mediterranean in term of population distribution (relative abundance indices) as well as demographic structures (length distributions, maturity stages, etc.)

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.

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 – 400 m) of the Maltese islands and to investigate the spatial distribution of the biotic assemblages that these ecosystems support.

2.3 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 was collected in summer 2004 from stations located at different depths between 100 m and 400 m on muddy bottoms (Fig. 2.1). 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, 22 m wide; with a 2 m vertical opening and 40 m in length and with a codend stretched mesh size of 20 mm (IFREMER GOC 73) 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 0.0625 m^2 box-corer (WILDCO®). Sediment granulometry and organic carbon were determined according to the procedures described by Buchanan (1984).

Since the MEDITS trawl survey was adopted in Malta in 2002, the sampling stations conducted in this study were located in trawled areas to avoid loss of gear during the first years of the survey. Furthermore a limited number of stations were conducted in the depth ranges examined due to limited funds. Hence the analysis from this chapter was limited by replicate stations and a small dataset; however the data analysis has given important information for more detailed subsequent studies.

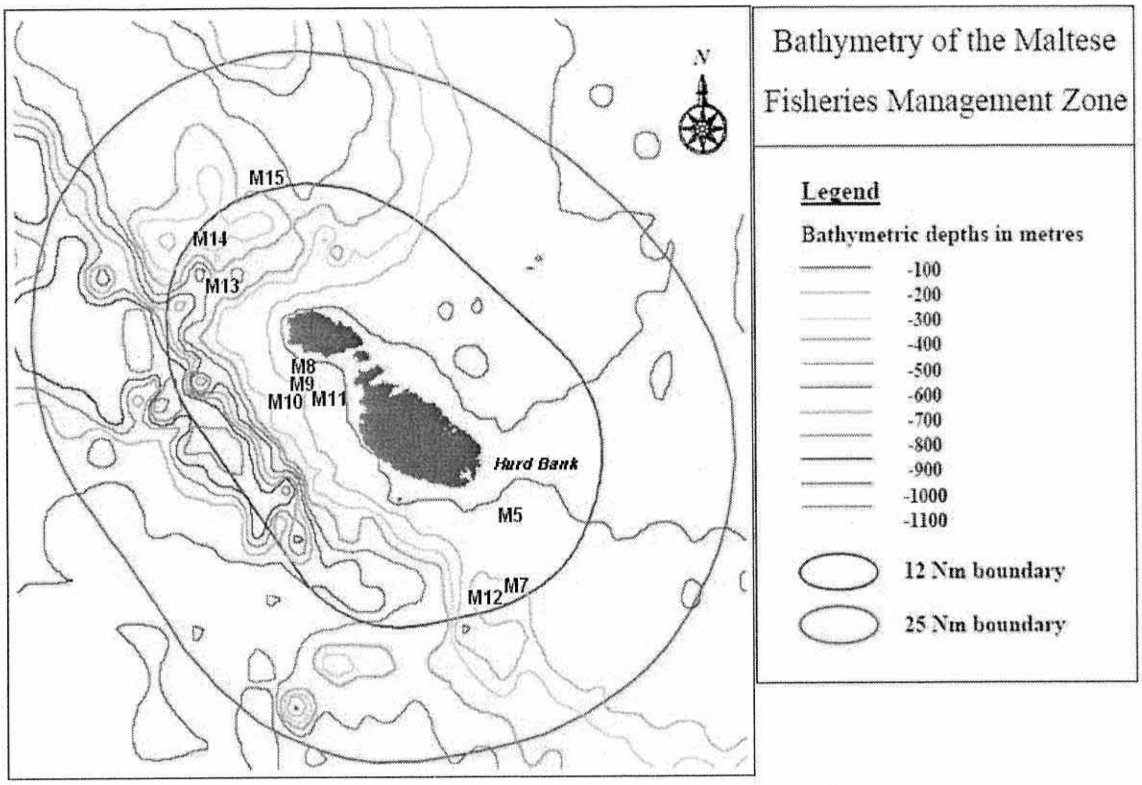

Figure 2.1 Map showing the Maltese FMZ with the sampling stations.

2.3.1 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, 1994).

Relationships between measured abiotic characteristics (depth and sediment characteristics see table 2.3) 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, 1994). All the analyses were undertaken using the PRIMER 5.22 statistical software package (Clarke & Warwick, 2001a).

2.4 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. 2.2a). 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 *Aristaeomorpha foliacea* (Giant Red Shrimp), *Nephrops norvegicus* (Norway Lobster) and *Galeus melastomus* (Blackmouth Catshark; Table 2.1). 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. 2.2b), but there was a greater variability for the offshore stations (Table 2.2). 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 2.2) 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. 2.2c; table 2.3) 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.

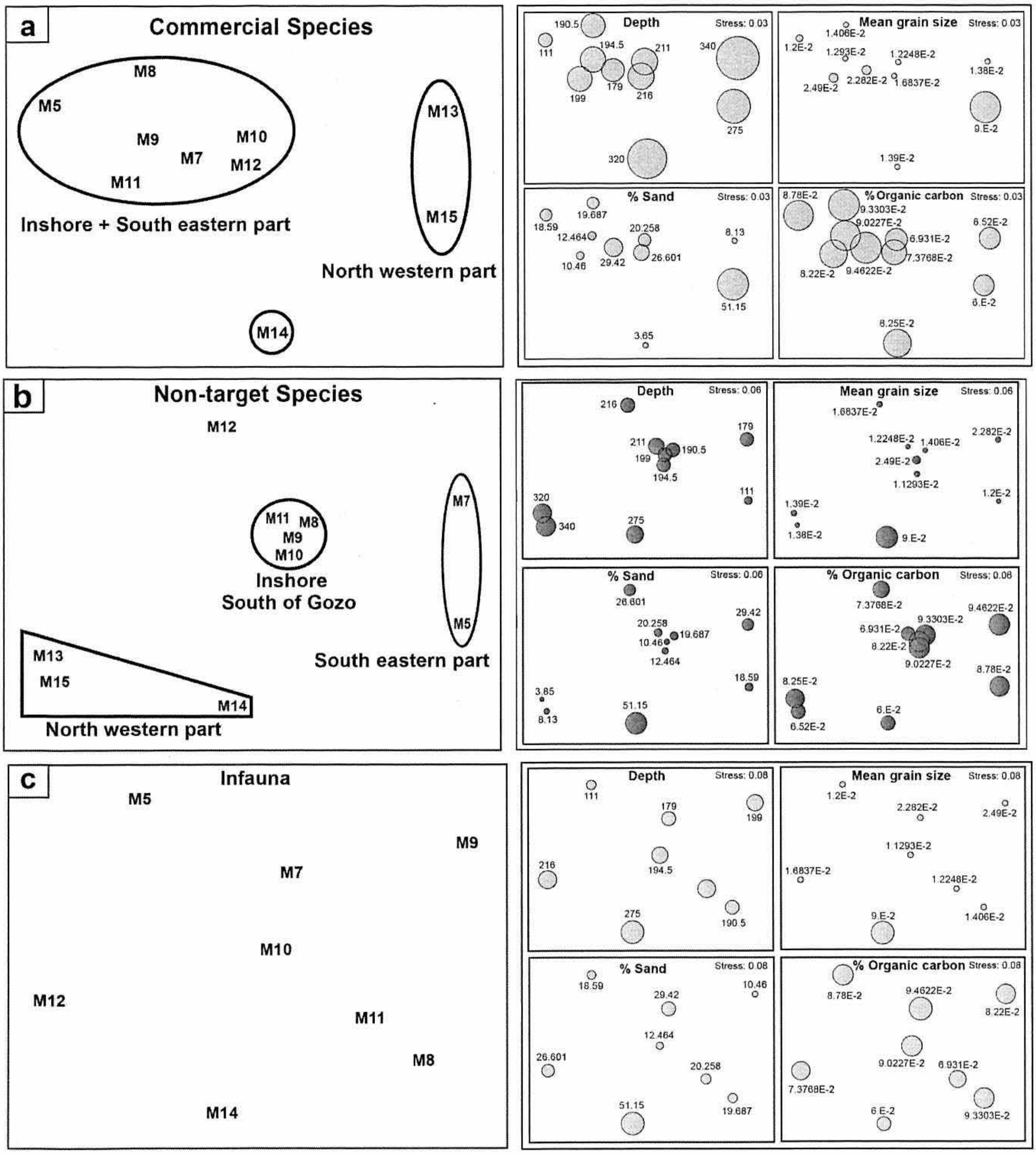

Figure 2.2 Non-metric multidimensional scaling (nMDS) plot for the ten sampling stations based on fourth root transformed species abundance data using the Bray-Curtis similarity measure. (a) Commercial species; (b) Non-target species, and (c) Infauna. Superimposed plots of scaled values of depth (m), mean grain size (μm), % sand, % organic carbon are also shown.

Table 2.1 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 stationsable

Taxon	Inshore + SE		NW	
	Mean abun. (ind. / km^2)	St. dev.	Mean abun. (ind. / km^2)	St. dev.
Aristaeomorpha foliacea	0	0	4569	±6310
Trachurus trachurus	±4494	±6228	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

Table 2.2 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 2.3). 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.

Table 2.3 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

2.5 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 (*Aristaeomorpha 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*, *Plesionika martia* 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, which is that certain common commercial species are commonly present at certain depths and 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 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.*, 2000b; Kaiser & Spencer 1994).

The stations to the SE of Malta have a high abundance of the crinoid *Leptometra phalangium* (Table 2.2). 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 200 m 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 (275 m) and M15 (340 m), to the northwest of the islands (the deepest stations sampled).

2.6 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.

Chapter 3

Differences in demersal community structure and biomass size spectra within and outside the Maltese Fishery Management Zone (FMZ).

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3.1 Abstract

We examined the protection effect of a long-established fisheries protection zone by studying the demersal communities and the biomass size spectra of specific taxonomic groups. The results of the community analysis are discussed within the context of the MEDITS trawl survey program, from which the data were derived with relevant management implications. The demersal fishery resources on the muddy bottoms of Maltese trawling grounds were stratified in four main depth ranges: 83–166 m (outer continental shelf), 140–230 m (shelf break), 270–440 m (shallow slope), and 466–701 m (deep slope). For the outer continental shelf significant differences were detected between the inside and outside zones. Stations from this stratum inside the protected zone had twice as much biomass as those outside and also larger individuals of some species (e.g. elasmobranchs). The depth strata identified do not coincide with those sampled in existing trawl survey programmes in the Sicilian Channel, which were set up without reference to demersal assemblage structure and its relation to depth. It is therefore clear that characterisation of the biotic assemblages is important in order to have a better sampling representation of each depth-stratum/assemblage type and that survey design must take this into consideration.

3.2 Introduction

Currently there is increasing interest in the ecosystem approach to fisheries management, (Link, 2002; Pitkitch *et al.*, 2004) and consequently a good knowledge of the components of the system is essential. In addition to the removal of target species, fishing with demersal towed gears can result in large-scale secondary ecological effects (Hall, 1999; Kaiser and de Groot, 2000; Kaiser *et al.*, 2006). In the Mediterranean sea, demersal stocks are generally recognized as depleted, fully-exploited or over-exploited (Farrugio *et al.*, 1993; Lleonart and Maynou, 2003; Rochet *et al.*, 2005). This has occurred mainly as a consequence of fleet over-capacity and the use of very small mesh sizes in trawl cod-ends that has increased fishing mortality and habitat degradation (Caddy, 1990; Fiorentini *et al.*, 1997; Ragonese *et al.*, 2002; Lleonart, 2005). This situation has raised concerns about the validity of the management actions implemented in the past (Corten, 1996) and has increased the pressure on scientists and stakeholders to adopt a precautionary and ecosystem-based approach to reduce the chances of overexploitation and/or collapse of fish stocks and to prevent ecosystem degradation. Areas in which fishing is restricted, or Marine Protected Areas (MPAs), are one tool designed to protect populations of commercially important stocks from overexploitation as well as other components of the ecosystem. In general, studies of MPAs have demonstrated that the abundance and size of harvested fish species increase when compared to unprotected adjacent areas (Rowley, 1994; Russ, 2002; Halpern, 2003). However most studies concern areas either completely closed to fishing or with very limited fishing activities. In the present study, we focus on the 25 Nautical Mile Maltese Fisheries Management Zone (FMZ) that has a strict control on trawling pressure and the management regime in this MPA addresses specifically fisheries (EC 813/2004).

Bottom trawling is an important component of most Mediterranean fisheries and, in many cases, it yields the highest earnings among all the fishing sub-sectors. In the Mediterranean, the seabed is trawled by commercial fishers at depths ranging from 50 m to 800 m (Farrugio *et al.*, 1993). The fishery has a multi-species composition and many of the commercially valuable species only appear seasonally in the catches (Caddy, 1993; Stergiou *et al.*, 1997). Trawl catches are composed of a highly diverse mix of fish (teleosts and elasmobranchs), cephalopods and crustaceans (decapods and stomatopods), together with several epifaunal macrobenthic invertebrates (Relini *et al.*, 1999).

The demersal fish, crustacean and cephalopod assemblages of Mediterranean trawl fishery grounds have been studied in the western, (Abella *et al.*, 1999; Abelló *et al.*, 2002; Colloca *et al.*, 2003; Massutí and Reñones 2005) and eastern (Tserpes *et al.*, 1999; Ungaro *et al.*, 1999; Labropoulou and Papaconstantinou, 2000; Kallianiotis *et al.*, 2004) basins, but there have been very few studies on such assemblages in the Sicilian channel (Patti *et al.*, 1994; Dimech *et al.*, 2005; Gristina *et al.*, 2006), which is the biogeographical border between the western and eastern sectors of the Mediterranean (Bianchi, 2007). Some studies have included an examination of the relationship between environmental factors (i.e. depth, water temperature, oxygen concentration and sediment type) and the distribution of the demersal assemblages (Biagi *et al.*, 1989; Sardà *et al.* 2004); others have attempted to relate the demersal assemblages to the structuring role of macroepibenthic communities (Gaertner *et al.*, 1999, 2002; Colloca *et al.*, 2003; Massutí and Reñones 2005). Most of these studies suggest that depth is a key driver of demersal assemblage composition and structure.

These studies provide important baseline information to underpin an ecosystem-based approach to the management of Mediterranean trawl fisheries. Understanding the relationship between restricted fishing zones, environmental factors and the communities of epibenthic invertebrates and those of demersal fish is important for management, especially if these relationships reveal links with different life-history stages or size-classes of target species (Blyth-Skyrme *et al.*, 2006). This knowledge becomes more critical since the collateral effects of the fishery can impact upon features (e.g. habitat or bioturbating fauna) that support key ecosystem functions (Kaiser and de Groot, 2000; Kaiser *et al.*, 2006).

At present, information is lacking on the distribution of biotic assemblages in relation to zones in which fisheries are restricted and a wider range of environmental parameters for many areas of the Mediterranean, even if such information is essential for the management of its living resources.

The present work aimed to study the conservation effect of the Maltese 25-Nautical Mile restricted fishing zone. The main hypothesis is that the exclusion of large-scale commercial fishing activities will have restricted overall fishing effort on demersal species. Specifically, the present study addressed the structure of the demersal assemblage, sediment characteristics, and the distribution of demersal resources on muddy bottoms in the depth range 80 m to 800 m inside the 25 Nautical Mile FMZ, and immediately outside it.

3.3 Materials and methods

3.3.1 Study area

Since 1971 Malta has managed a 25-Nautical Mile Exclusive Fishing Zone (Fig. 3.1), covering an area of 11980 km^2, which, after Malta became a member of the European Union in 2004, was retained as a Fisheries Management Zone (FMZ) (Council of the European Union, 2004). The objectives of the original Exclusive Fishing Zone (EFZ) were to protect the local artisanal fisheries from foreign large-scale fishing, especially trawling. Until recently, the fishing regulations in force in the EFZ were those published in 1934 (Fish Industry Act), with minor changes over the years (Camilleri, 2005), that included a restriction on trawling within Maltese territorial waters (3 nautical miles from the coastline; the restriction was maintained at 3 nautical miles even after the extension of Maltese territorial waters to 12 nautical miles). Prior to Malta's accession to the EU a new management regime was proposed (Camilleri, 2003), agreed upon and later implemented after accession through Council Regulation EC 813/2004, which, inter alia, limited trawling operations to specified areas based on the trawlable grounds identified during a survey in 1978 made in collaboration with the Food and Agriculture Organization of the United Nations (FAO) (Giudicelli, 1978).

3.3.2 Sampling methodology

The present study was conducted within the 25 NM FMZ around the Maltese islands and the sea area immediately outside this zone that comprises the General Fisheries Commission for the Mediterranean (GFCM) geographical sub-area 15, as part of the ongoing MEDITS trawl survey programme (Bertrand *et al.*, 2002). Experimental otter trawl samples were collected by the RV Sant`Anna in June/July of 2003, 2004 and 2005 from 45 stations located at different depths between 80 m and 800 m (Fig. 3.1). Each haul lasted for 30 min at depths less than 200 m and 60 min at depths between 200-800 m, and trawl speed was ca. 3 knots. Samples were collected using a 20-22 m wide and 40 m long experimental otter trawl net with a 2-2.5 m vertical opening and a cod end stretched mesh size of 20 mm (IFREMER GOC 73) (Fiorentini *et al.*, 1999). Seawater bottom temperature was measured using a temperature probe (Minilog Vemco©)

attached to the net. The entire biotic component from each haul was sorted, after which the fauna were identified, weighed and counted.

In 2004 and 2005, 3 replicate samples for sediment analyses were collected from 26 stations (marked with an asterisk in Fig. 3.1) using a WILDCO® 0.0625 m^2 box-corer. Of the 26 stations sampled, 12 were from the 100-200 m MEDITS depth stratum, seven were from the 200-500 m MEDITS depth stratum, and the other seven were from the 500-800 m MEDITS depth stratum. Sediment granulometry and percentage organic carbon were determined according to the procedures described by Buchanan (1984). The percentage dry weight of the different sediment fractions was calculated. Folk and Ward statistical sediment descriptors, including mean sediment grain size, sediment sorting, skewness and kurtosis, were calculated using the GRADISTAT version 4.0 software (Blott and Pye, 2001). Data for macrofauna (infauna and epifauna) from these box-core samples were not used in the present study since the total abundance was very low for all stations, ranging from ca. 2 to 10 individuals per core and averaging 64 ind./m^2 with a high variability (Dimech *et al.*, 2005).

3.3.3 Statistical analyses

Univariate indicators, including abundance indices, biodiversity indices and slopes and intercepts of biomass size spectra, were computed for the stations sampled inside and outside the FMZ including: the total number of individuals per km^2, total biomass per km^2, total number of species, Shannon-Weiner diversity (H') and Pielou's evenness (J'). Abundance data was used for the calculation of diversity indices. These indicators were calculated for each assemblage group identified a posteriori from multivariate analysis of the data in order to eliminate the confounding effect of change in the demersal communities that occurs with depth in the large depth range examined (80 – 800 m).

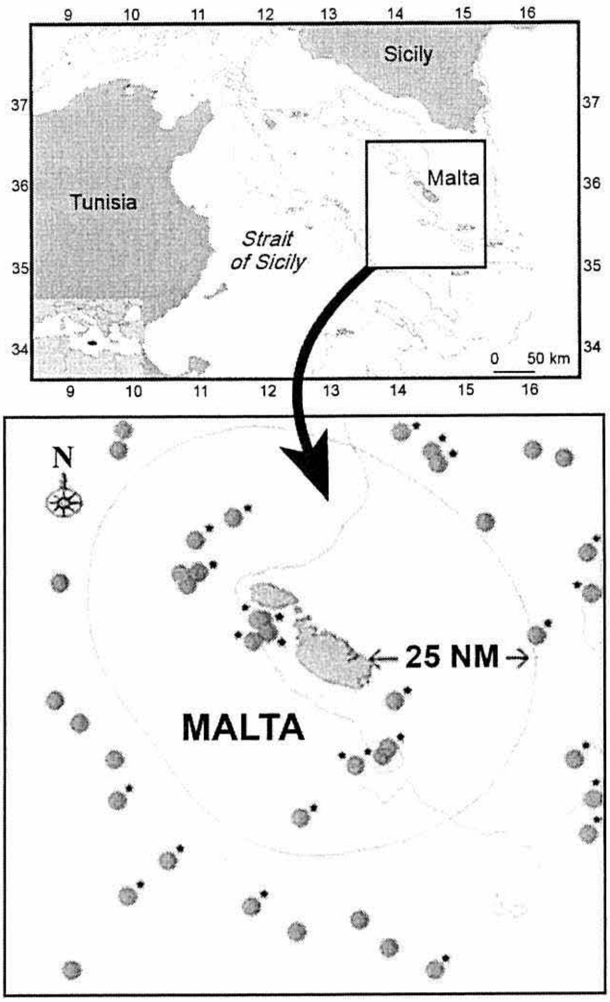

Figure 3.1 Map of the study area showing the location the General Fisheries Commission for the Mediterranean geographical sub-area 15 (the quadrilateral south of Sicily). The oval round Malta represents the boundary of the Maltese 25 NM Fisheries Management Zone (FMZ). The filled circles mark the position of the trawl sampling stations; stations from where box-cores were collected are indicated by an asterisk. The 200 m depth contour is also shown.

The univariate indices (density, DI, and biomass, BI) for each station were standardised per km^2, and analysed using multivariate classification and ordination techniques. Species whose percentage abundance and biomass were less than 0.01% of the total sample were removed from the analyses. In order to reduce the influence of abundant species and increase the importance of less common species a similarity matrix was constructed from the fourth-root transformed data using the Bray-Curtis similarity index (Clarke and Warwick, 2001a). Non-metric multidimensional scaling (nMDS) ordination was applied. Since the biomass data yielded more clearly interpretable results, only these are presented and used for further analysis. The SIMPER (similarity percentages) procedure was used to determine which species contributed most to the similarity within each grouping of stations and to the dissimilarity between the groupings that were defined a posteriori (Clarke and Warwick, 1994). In order to check for temporal differences between the identified clusters that may affect the analysis between the stations inside and outside the FMZ, the Analysis of Similarities (ANOSIM) routine was used (Clarke and Warwick, 1994). Relationships between the measured abiotic parameters (depth, temperature and sediment characteristics) and the composition of the demersal assemblages were determined using the BIOENV procedure (Clarke and Ainsworth, 1993), and by superimposing scaled individual variables onto the sample locations on the two-dimensional nMDS ordination plots (Field *et al.*, 1982; Clarke and Warwick, 2001a). All the analyses were undertaken using the PRIMER 6 statistical software package (Clarke and Warwick, 2001a).

To determine if the assemblage groups identified a posteriori exhibit any differences in body-size distribution inside and outside the Maltese FMZ, biomass size-spectra were plotted. In the classical pyramids of biomass of ecological foodwebs, the largest species tend to occur at the top. If the pyramid is turned on its side one obtains the classical plot of biomass vs weight. When fishing perturbates the system by removing individuals of a larger size classes this should be reflected by a sharper peak and hence a steeper slope with a more negative value. Size spectra were calculated for each assemblage inside and outside the FMZ based on data from each of the three separate years, by using the weights of individuals from all taxonomic groups, including teleosts, elasmobranchs, crustaceans and cephalopods. Since different hauls did not sweep equal areas of the bottom, especially due to the large difference in the depth range, weights were standardized per km^2, after which each individual was assigned to a weight-class (log_{10} weight in g). The data were normalised and the logarithm of the biomass was calculated. Lower and upper size classes were excluded to avoid data artifacts due to poor retention in the gear (Duplisea *et al.*, 1997; Jennings *et al.*, 2001b).

For the univariate abundance and biodiversity indices and slopes and intercepts of the biomass size-spectra a two-way General Linear Model analysis of variance (2-Way

GLM ANOVA) was used to test for significant differences between different assemblages (identified a posteriori from the multivariate analyses) and to detect significant differences between the stations for the groups identified inside and outside the FMZ. GLM ANOVA nalysis was used since the number of replicate stations for the analysis of inside vs outside by assemblage type was not the same (see Table 3.4).

3.4 Results

A total of 189 species (26 elasmobranchs, 111 teleosts, 26 decapods and 26 molluscs) were identified; teleosts were the dominant taxon sampled by the fishing gear in terms of both density and biomass index (Table 3.1). When classified on the basis of biomass, five main groups resulted at a similarity of 46% (Fig 3.2). These groups represented two different geographical locations of the outer continental shelf (A and B, Fig. 3.2), the shelf break (140 – 273 m), shallow slope (240 – 440 m) and the deep slope (466 – 701 m). The species responsible for the four assemblages revealed by nMDS, as determined by SIMPER, show that a large number of species contributed to the overall similarity and there were clearly dominant species: Continental Shelf - *Scyliorhinus canicula*, *Mullus barbatus* and *Merluccius merluccius*; Shelf Break - *Capros aper*, *Argentina sphyraena*, *Scyliorhinus canicula* and *Merluccius merluccius*; Shallow Slope - *Chlorophthalmus agassizi*, *Merluccius merluccius* and *Caelorhynchus caelorhynchus*; Deep Slope - *Galeus melastomus*, *Aristaeomorpha foliacea*, *Hoplostethus mediterraneus* and *Merluccius merluccius* (table 3.2). Interestingly, some species are present in most of the assemblage types identified but they differ in their percentage contribution to assemblage structure; for example, *Merluccius merluccius* had different mean densities in the different groups identified (table 3.2).

Table 3.1 Contribution of each taxon to the composition of the demersal assemblages in terms of density and biomass for the years under study

Taxon	Relative Density (%)				Biomass (%)			
	2003	2004	2005	Mean ± s.d.	2003	2004	2005	Mean ± s.d
Teleosts	68.11	75.59	94.91	79.54 ±13.83	64.11	66.92	83.12	71.38 ±10.26
Elasmobranchs	1.32	1.40	0.60	1.11 ± 0.44	18.76	20.98	11.18	16.97 ±5.14
Decapods	17.36	19.16	3.15	13.22 ± 8.77	6.11	7.06	3.53	5.57 ±1.82
Molluscs	13.21	3.86	1.34	4.69 ± 6.26	11.02	5.04	2.17	6.08 ±4.52

Table 3.2 Species which contributed to 90% of the similarity as determined by the SIMPER procedure							
Outer shelf A (OSA)				**Outer shelf B (OSB)**			
Average similarity: 51.60				Average similarity: 57.29			
Species	Av. BI	sd	Cum.%	Species	Av. BI	sd	Cum.%
Scyliorhinus canicula	2.36	0.7	7.22	*Merluccius merluccius*	2.42	0.5	9.49
Mullus barbatus	2.58	0.7	14.45	*Trachurus trachurus*	2.6	1.4	17.76
Raja clavata	2.57	1.6	21.28	*Parapenaeus longirostris*	2.41	1.06	25.89
Merluccius merluccius	2.31	1.4	27.6	*Illex coindetii*	2.07	1.2	32.52
Aspitrigla cuculus	2.03	0.4	33.49	*Argentina sphyraena*	1.77	0.79	38.21
Sepia orbignyana	2.14	0.5	39.38	*Alloteuthis media*	1.55	0.4	43.79
Serranus hepatus	1.96	0.4	45.26	*Mullus barbatus*	1.66	0.93	49.2
Lepidotrigla cavillone	2.06	1.3	50.65	*Trisopterus minutus capelanus*	1.45	0.8	54.12
Citharus linguatula	1.73	0.3	55.41	*Aspitrigla cuculus*	1.57	1.08	58.82
Spicara flexuosa	2.16	2.2	59.57	*Macrorhamphosus scolopax*	1.51	1.17	63.1
Trachurus trachurus	2.58	2.7	63.67	*Citharus linguatula*	1.17	0.51	67.24
Argentina sphyraena	1.68	1.1	67.55	*Scaeurgus unicirrhus*	1.22	0.9	71.05
Macrorhamphosus scolopax	2.41	2.6	71.2	*Serranus hepatus*	1.29	0.91	74.79
Serranus cabrilla	1.73	1.7	74.48	*Capros aper*	1.09	0.84	77.96
Dentex macrophthalmus	1.51	1.5	77.72	*Spicara flexuosa*	1.45	1.71	81.06
Scaeurgus unicirrhus	1.27	0.3	80.85	*Zeus faber*	1.33	1.32	84.12
Boops boops	1.38	1.5	83.25	*Lepidotrigla cavillone*	1.04	1.49	86.18
Mullus surmuletus	1.28	1.8	85.31	*Todaropsis eblanae*	0.81	1.09	87.87
Raja miraletus	1.41	2.9	86.93	*Sepia orbignyana*	0.8	1.21	89.35
Trisopterus minutus capelanus	1.06	1.5	88.49	*Sepiola* spp	0.63	0.77	90.81
Alloteuthis media	0.93	1.3	89.91				
Illex coindetii	1.2	2.4	91.26				
Shallow slope (SL)				**Shelf break (SS)**			
Average similarity: 59.58				Average similarity: 58.19			
Species	Av. BI	sd	Cum.%	Species	Av. BI	sd	Cum.%
Chlorophthalmus agassizi	3.48	1.5	8.46	*Capros aper*	3.82	1.32	8.68
Merluccius merluccius	2.61	0.4	16.07	*Argentina sphyraena*	2.84	1.1	15.48
Caelorhynchus caelorhynchus	2.84	1.4	23.15	*Scyliorhinus canicula*	2.64	1.35	22.06
Gadiculus argenteus	2.49	0.7	29.65	*Merluccius merluccius*	2.36	0.5	28.42
Parapenaeus longirostris	2.17	0.5	35.74	*Illex coindetii*	2.12	1.25	33.19
Scyliorhinus canicula	2.16	0.9	41.36	*Macrorhamphosus scolopax*	2.25	1.42	37.86
Raja clavata	2.51	1.8	46.88	*Scaeurgus unicirrhus*	1.58	0.27	42.1
Todaropsis eblanae	2	1.4	51.87	*Parapenaeus longirostris*	1.93	1.2	46.32
Helicolenus dactylopterus dactylopterus	1.94	0.9	56.58	*Todaropsis eblanae*	1.83	0.54	50.52
Phycis blennoides	1.76	0.8	61.05	*Raja clavata*	2.18	2	54.72
Nephrops norvegicus	1.79	1	65.39	*Peristedion cataphractum*	1.98	1.21	58.91

Peristedion cataphractum	1.72	0.8	69.52	*Trachurus trachurus*	1.69	1.24	62.17
Argentina sphyraena	1.72	1.1	73.59	*Helicolenus dactylopterus dactylopterus*	1.42	0.65	65.39
Lepidopus caudatus	2.01	2.1	77.04	*Sepia orbignyana*	1.38	0.94	68.26
Raja oxyrinchus	1.49	1.5	79.89	*Mullus barbatus*	1.5	1.55	71.02
Squalus blainvillei	1.56	2.1	82.31	*Alloteuthis media*	1.16	0.83	73.47
Capros aper	1.41	1.7	84.35	*Zeus faber*	1.46	1.39	75.91
Lophius budegassa	1.02	1.3	86.12	*Mullus surmuletus*	1.26	1.15	78.23
Hymenocephalus italicus	1	1.7	87.52	*Lepidotrigla dieuzeidei*	1.61	2.44	80.53
Scaeurgus unicirrhus	0.71	1	88.74	*Lophius budegassa*	1.27	1.35	82.68
Sepiola spp	0.69	1	89.88	*Citharus linguatula*	1.03	0.93	84.74
Galeus melastomus	0.76	1	90.97	*Raja miraletus*	1.2	1.3	86.8
				Trigla lyra	1.3	1.69	88.83
				Aspitrigla cuculus	1.05	1.59	90.31
Deep Slope (DS)							
Average similarity: 59.45							
Species	Av. BI	sd	Cum.%				
Galeus melastomus	2.45	0.9	9.44				
Aristaeomorpha foliacea	2.21	0.6	18.59				
Hoplostethus mediterraneus	1.98	0.6	25.82				
Merluccius merluccius	2.13	1.3	32.78				
Plesionika martia	1.64	0.4	39.57				
Nezumia sclerorhynchus	1.65	0.8	45.91				
Phycis blennoides	1.74	1	52.08				
Caelorhynchus caelorhynchus	1.67	0.9	57.79				
Helicolenus dactylopterus dactylopterus	1.93	1.4	63.47				
Etmopterus spinax	1.64	1	69.01				
Hymenocephalus italicus	1.2	0.4	73.71				
Nephrops norvegicus	1.32	0.9	77.51				
Todarodes sagittatus	1.22	1.7	80.62				
Parapenaeus longirostris	1.11	0.9	83.7				
Raja oxyrinchus	1.36	2.1	86.56				
Chlorophthalmus agassizi	1.45	1.8	89.39				
Chimaera monstrosa	1.19	1.7	91.7				

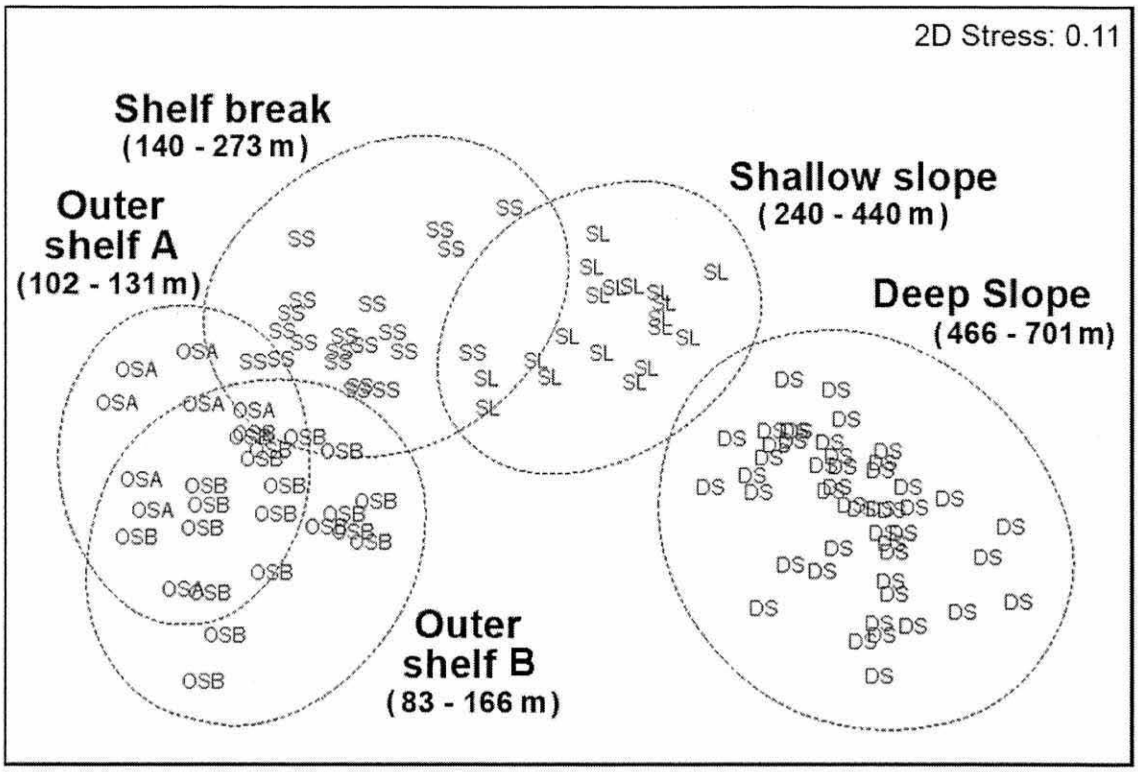

Figure 3.2 Non-metric multidimensional scaling (nMDS) plot for the sampling stations for all the three years based on the biomass data. The ovals show the groups generated by cluster analysis. OSA – Outer shelf A; OSB – Outer shelf B; SS – Shelf break; SL – Shallow slope; DS – Deep slope.

Analysis of similarities (ANOSIM) showed that the groups generated by nMDS were not significantly different (R= 0.137) between the years under study. The lowest dissimilarity was between the shallower groups while the greatest dissimilarity was between the deep and shallow groups (Table 3.3). For the univariate parameters estimated (Fig. 3.3), the resuting number of replicate stations available for the analysis are shown in Table 3.4. The differences between the station groups identified by the classification and ordination analyses were all significant (GLM ANOVA P< 0.05; Table 3.5) . Total density and the biomass index were highest for the Outer Shelf A (inside FMZ) and Shelf Break stations. Both biomass and abundance were very low in the Outer Shelf B (outside FMZ) group when compared to the other group of the same depth range, that is, Outer Shelf A. Between the stations inside and outside the FMZ significant differences (GLM ANOVA P< 0.05; Table 3.5) were only detected for the biomass index. Evenness and diversity values were fairly similar among groups, but were lowest for the Shelf Slope. Although the Deep Slope group had the lowest abundance and biomass values, diversity and evenness were relatively high when compared with the other groups.

Table 3.3 Average percentage dissimilarity between species for the groups obtained by the ordination techniques as determined by the ANOSIM procedure. See legend to Fig. 3.2.				
Group	OSA	OSB	SS	SL
OSA				
OSB	55.56			
SS	59.03	54.29		
SL	77.31	71.81	60.46	
DS	91.58	87.72	83.19	65.22

The correlation analyses undertaken using the BIOENV procedure gave relatively high values of Spearman's coefficient for depth, temperature and any combination associated with these parameters (Fig. 3.4). For all the assemblage types, a combination of four sediment characteristics: % very coarse sand, % medium sand, % coarse sand and sorting coefficient, gave the highest Spearman correlation value (0.344) when considering sediment characteristics alone. Most sediment granulometric parameters such as mean grain size and % very coarse sand, gave very low correlation values and do not seem to be important in predicting the structure in the demersal assemblages (Fig. 3.4).

Table 3. 4 Number of replicate stations used for the 2-Way GLM ANOVA after the the identification a posteriori of the assemblage types by multivariate analyses. OS Outer shelf; SS – Shelf break; SL – Shallow slope; DS – Deep slope.

Assemblage type	No. of Station Inside	No of Stations Outside
OS	8	21
SS	18	3
SL	5	14
DS	11	37

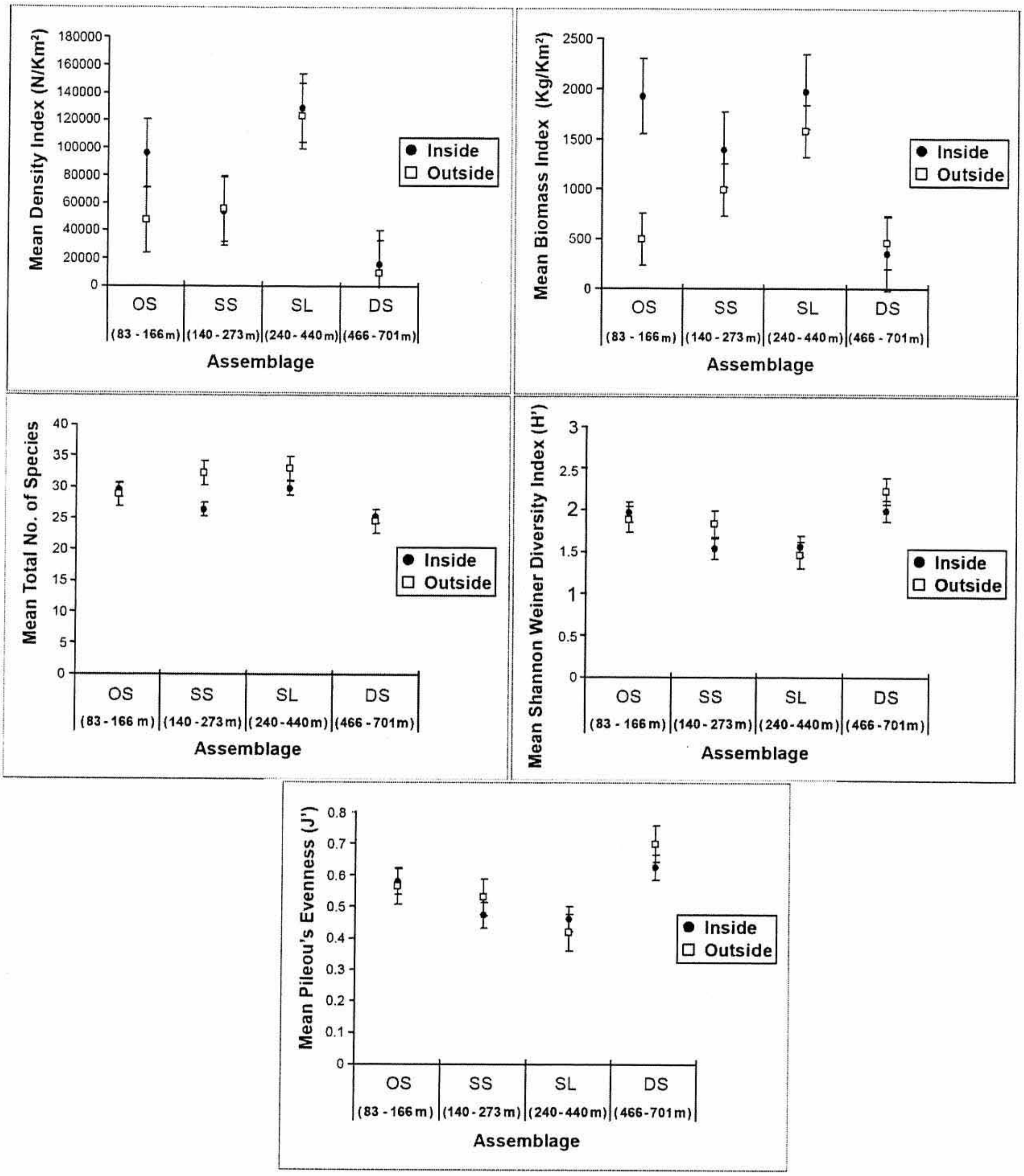

Figure 3.3 Mean (± standard error) values of mean density index in N/km^2, mean Biomass index in kg/km^2, mean number of species, mean Shannon-Weiner diversity (H') and mean Pielou`s evenness (J') for each of the four main groups of stations. OS Outer shelf; SS – Shelf break; SL – Shallow slope; DS – Deep slope.

Table 3.5 Summary of the outcome of the 2-Way GLM ANOVA for the effects of assemblages and inside/outside the 25 nautical mile FMZ and the interaction between these factors (see Figs. 3 and 5) for Density Index (DI) in N/km^2, mean Biomass Index (BI) in kg/km^2, mean number of species (S), mean Shannon-Weiner diversity (H') and mean Pielou`s evenness (J') and slopes (s) and intercepts (i) of the biomass size spectra. The characters in bold show a significant differences at P < 0.05.

		DI		BI		S		J'		H'	
	df	**F**	**P**	**F**	**P**	**F**	**P**	**F**	**P**	**F**	**P**
Corr. Model	7	8.63	<0.01	6.73	<0.01	5.76	<0.01	12.81	<0.01	7.86	<0.01
Intercept	1	80.72	<0.01	91.65	<0.01	2391.83	<0.01	1803.75	<0.01	1636.76	<0.01
Assemblage	3	10.87	**<0.01**	6.65	**<0.01**	7.03	**<0.01**	16.08	**<0.01**	9.27	**<0.01**
Inside/Outside	1	0.98	0.32	4.94	**0.03**	2.42	0.12	0.54	0.47	0.95	0.33
As. *Ins/Out.	3	0.78	0.51	2.84	**0.04**	2.07	0.11	1.35	0.26	1.51	0.22
Error	109										
Total	117										
Corr. Total	116										

		All Taxa (s)		**Teleosts (s)**		**Elasmobranchs (s)**		**Crustaceans (s)**	
Corr. Model	7	4.13	0.01	11.99	<0.01	4.07	0.01	0.88	0.54
Intercept	1	449.15	<0.01	478.64	<0.01	28.02	<0.01	62.84	<0.01
Assemblage	3	6.10	**0.01**	21.27	**<0.01**	2.49	0.10	1.46	0.27
Inside/Outside	1	8.17	**0.01**	14.77	**<0.01**	2.69	0.12	0.65	0.43
As. *Ins/Out.	3	0.81	0.51	1.81	0.19	6.10	**<0.01**	0.16	0.92
Error	16								
Total	24								
Corr. Total	23								

		All Taxa (i)		**Teleosts (i)**		**Elasmobranchs (i)**		**Crustaceans (i)**	
Corr. Model	7	3.84	0.01	10.19	<0.01	8.57	<0.01	1.65	0.20
Intercept	1	2176.74	<0.01	2631.14	<0.01	828.88	<0.01	584.69	<0.01
Assemblage	3	5.61	**<0.01**	15.30	**<0.01**	6.24	**<0.01**	1.03	0.41
Inside/Outside	1	8.40	**<0.01**	17.10	**<0.01**	0.60	0.448	0.03	0.88
As. *Ins/Out.	3	0.55	0.65	2.77	0.08	13.56	**<0.01**	2.19	0.14
Error	16								
Total	24								
Corr. Total	23								

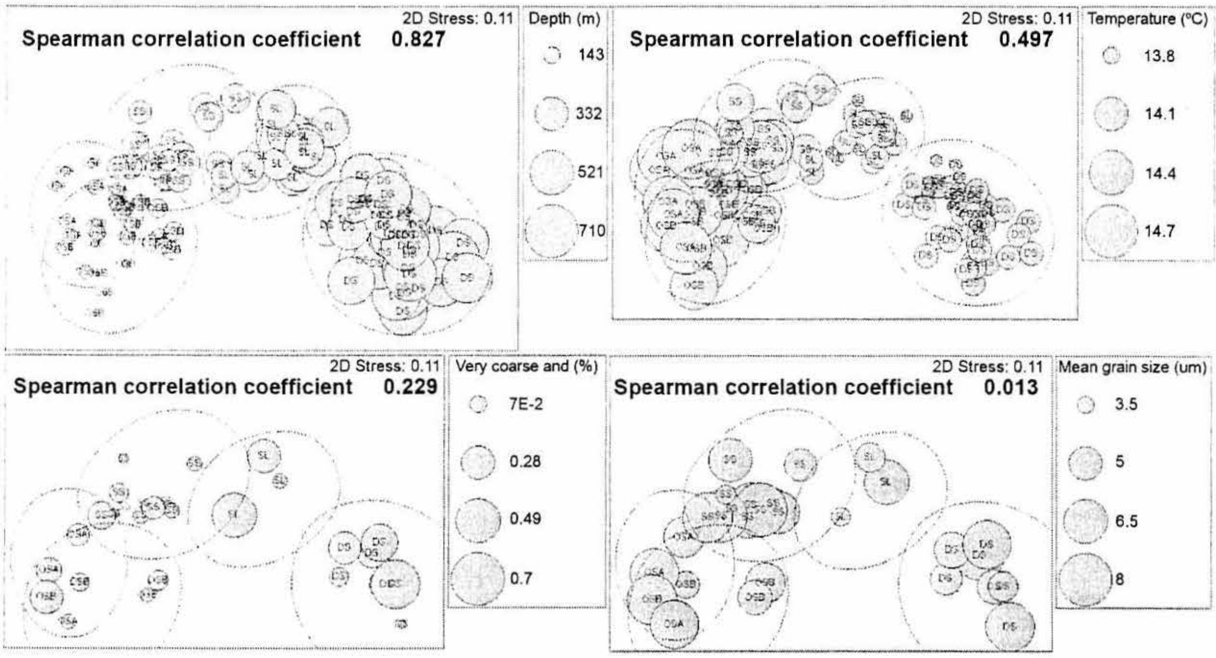

Figure 3.4 The nMDS plot from Figure 3.2 with scaled values of (A) depth, (B) temperature, (C) % very coarse sand, and (D) % mean sediment grain size (μm). The Spearman correlation coefficient for each parameter is also shown.

When considering the biomass size spectra for the analysis between the inside and outside stations significant differences (GLM ANOVA P< 0.05; Table 3.5) were detected for all taxa grouped together and teleosts both for the slopes and gradients. The more negative slopes show a clear impact on the communities outside the FMZ. For the elasmobranchs the frequency distribution of the $\log_{10}$ of the biomass size classes was plotted for each assemblage and for the inside and outside stations (Fig. 3.6). There is a clear low number of size classes in the outside stations of the outer shelf and shelf break assemblages.

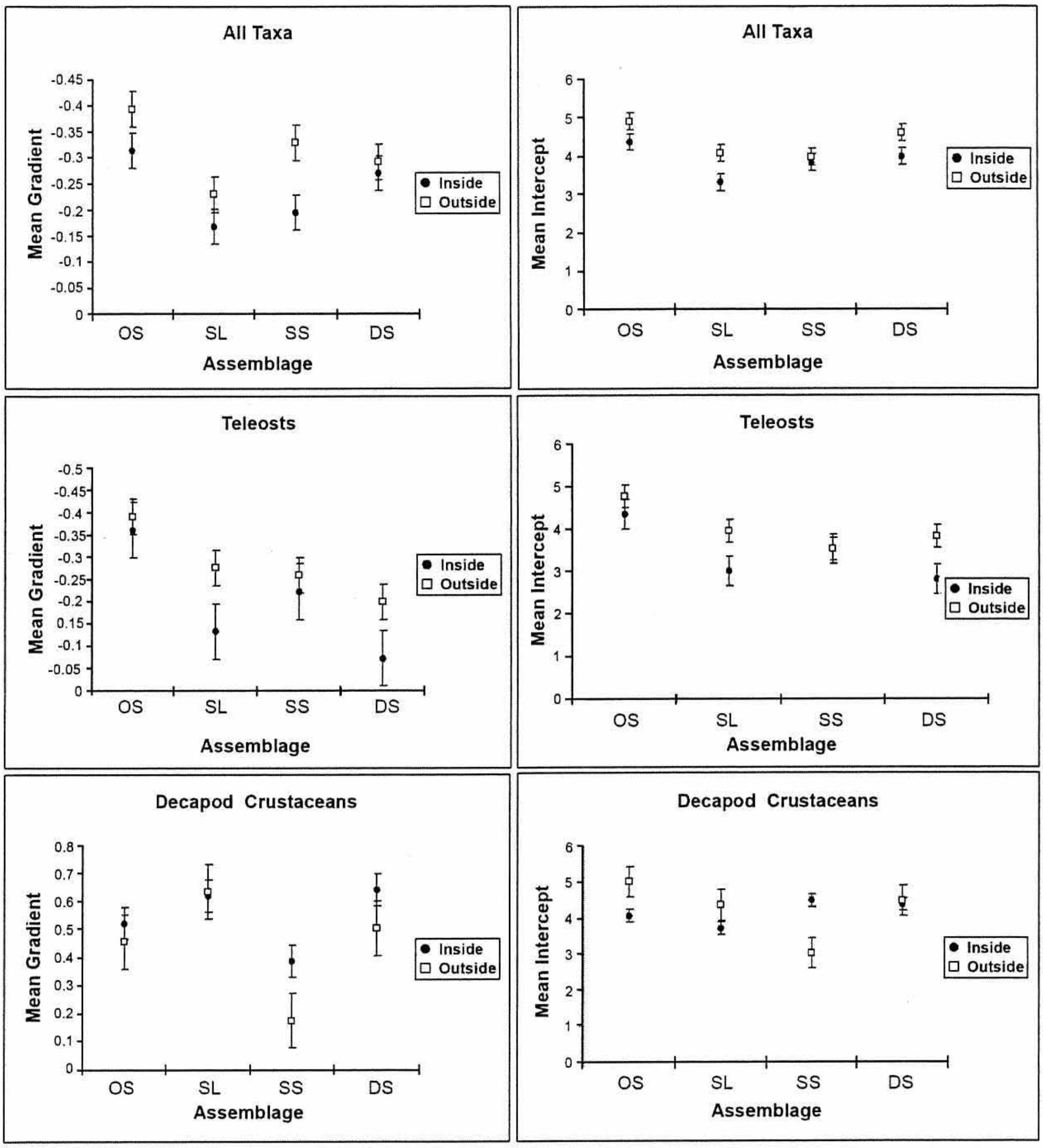

Figure 3.5 Variation in the slopes and intercept (± 1 S.E.) of the biomass size-spectra for the different taxonomic groups, by assemblage type, and inside and outside the Maltese 25 Nautical Mile Fisheries Management Zone. OS – Outer shelf; SS – Shelf break; SL – Shallow slope; DS – Deep slope.

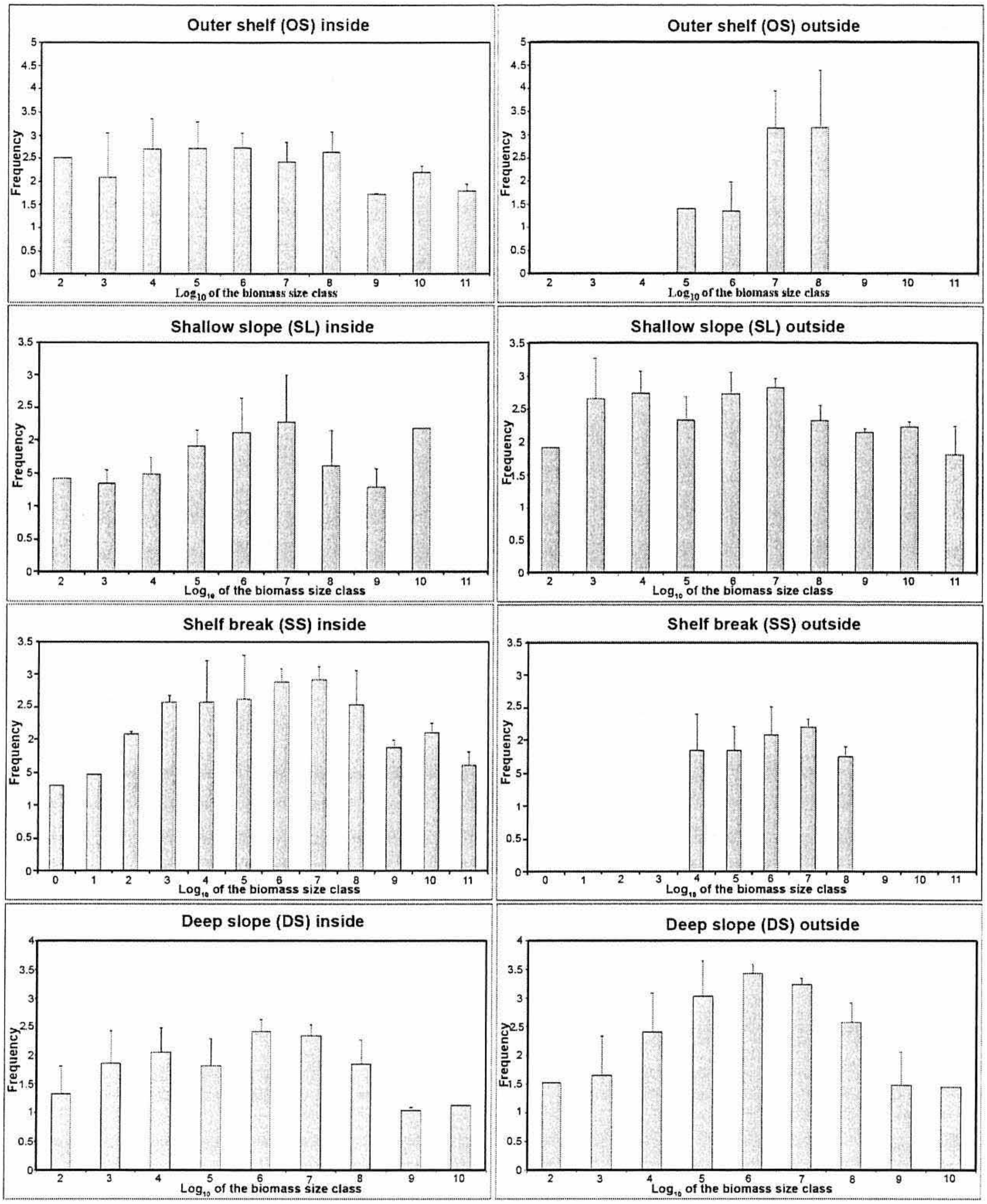

Figure 3.6 Biomass size frequency distribution of elasmobranches (± 1 S.E.) by assemblage type, and inside and outside the Maltese 25 Nautical Mile Fisheries Management Zone. OS – Outer shelf; SS – Shelf break; SL – Shallow slope; DS – Deep slope.

3.5 Discussion

Based on our results, the fishery resources of Maltese trawling grounds are stratified into four main depth ranges, which agrees with other studies in the Mediterranean that have shown similar depth ranges for deep water demersal assemblages (Table 3.6). The multivariate analyses also differentiated two different assemblages on the offshore continental shelf (Outer Shelf A and B). A major difference between these two assemblages was that one is found inside the 25 NM FMZ while the other is found in the sea immediately outside the zone. None of the environmental parameters measured seemed to explain the difference between these two assemblages. Depth, temperature and sediment characteristics, which are the main factors structuring benthic and demersal assemblages, are similar in the two areas (Biagi *et al.*, 1989).

The difference between these two assemblages may be related to fishing pressure since trawling effort is very limited on the continental shelf inside the FMZ. Only 15 trawlers that are restricted in power and length by regulation (Council of the European Union, 2004) are allowed to fish in the zone, while there are no legal restrictions on trawling outside the zone. Furthermore, most of the trawlers that fish inside the zone target red shrimp *Aristaeomorpha foliacea* at a depth ca. 600 m due to the availability of good trawling grounds at the north western part of the islands which are very close to the shore. Italian trawling fleets regularly trawl the areas outside the 25 NM FMZ since it is very close to the main Sicilian fishing ports. The differences between the two continental shelf assemblages were mainly quantitative (table 3.2) with species groups sensitive to trawling, such as elasmobranchs (for example, *Scyliorhinus canicula* and *Raja clavata*), being very common inside the zone, and practically absent outside the 25 NM FMZ. These species were also those most responsible for the difference between the two assemblages. For the Outer Shelf, the analysis of the size-spectra also indicated that elasmobranchs were larger in size inside the FMZ. Furthermore the $\log_{10}$ biomass size classes in the outer shelf and shelf break assemblages are less than half that of the inside stations indicating a clear impact on the community of elasmobranchs in the outside stations. The Outer Shelf region outside the FMZ has half the biomass (Camilleri, 2000; Camilleri, 2002) and abundance than that inside the 25 NM zone (see

Fig. 3.3), and reduced biomass and abundance is a common feature of heavily trawled areas (Kaiser and de Groot, 2000).

Table 3.6 A summary of studies on deep water assemblages in the Mediterranean. The studies marked in asterix have used an a posteriori approach to determine the assemblage structure

Authors	**Location**	**Assemblage type**	**Depth ranges used in the analysis (m)**	**Years**
Moranta *et al.*, (1998)	Western Mediterranean	Fish assemblages	200-400; 400-800; 800-1400; 1400-1800	
Tserpes *et al.*, (1999)	Eastern Mediterranean (Sothern Aegean)	Demersal assemblages	0-100; 100-200; 200-500; 500-800	1996-97
Ungaro *et al.*, (1999)*	Central Mediterranean (South Adriatic)	Fish assemblages	31-329; 281-551	1996-97
Labropoulou and Papaconstantinou (2000)	Eastern Mediterranean	Fish assemblages	100-200; 200-500	1990-1993
Colloca *et al.*, (2003)*	Central Mediterranean (Tyrrhenian sea)	Demersal assemblages	12-47; 32-133; 128-317; 195-496; 388-616	1997-98
		Cephalopod assemblages	16-407; 281-538; 315-547	1996-97
		Crustacean assemblages	29-131; 77-329; 346-551	1996-97
Kallianiotis *et al.*, (2004)	Eastern Mediterranean (North Aegean Sea)	Fish assemblages		1996-2000
	Thracian sea		10-50; 50-100	
	Thermaikos Gulf		10-100; 50-100; 100-200; 50-500	
	Central Aegean sea		100-500; 200-600	
D'Onghia *et al.*, (2004)*	Mediterranean	Fish assemblages	600-650; 800-1300; 1300-4000	2001
Massutí and Reñones (2005)*	Balearic Islands, NW Mediterranean	Demersal assemblages	41-76; 69-147; 139-235; 326-444; 472-686; 649-745	2001

When considering the size-spectra over the entire depth range studied, the Outer Shelf area is different from the deeper areas. The size spectra analysis also showed differences between the inside and outside stations for the Shelf Break, Shallow Slope and Deep Slope assemblages. These differences were not detected by univariate or multivariate community descriptors. The mean size spectra for the teleosts show a clear pattern of decreasing mean body size with increasing depth. The outer shelf assemblages are dominated by high abundances of small body-sized fishes (Fig. 3.5) and as the depth increases, the preponderance of larger body-sized fishes increases although overall abundance decreases. There is a transition from one assemblage to another as the depth increases with a shift in the community from one dominated by fish to one dominated by decapods (mostly shrimps). The elasmobranchs for example in the shallower assemblages are dominated by larger body-sized individuals (e.g. *Raja clavata* and *Squalus blainvillei* and *Mustelus* spp.) but the large sized elasmobranchs decline in predominance in the deeper waters with the occurrence of smaller sized individuals (e.g. *Galeus melastomus* and *Etmopterus spinax*).

In this study, the assemblages were determined a posteriori followed by further analysis to determine changes in community descriptors between the inside and outside areas of the FMZ. A number of studies in the Mediterranean have analyzed assemblages according to predefined depth strata, which usually depend on survey protocols formulated with little or no consideration to biologically relevant bathymetric zonation. For example, in the present study, the data used were obtained from the Mediterranean International Trawl Survey (MEDITS) programme, which samples the following predefined depth strata on muddy bottoms: 51-100 m, 101-200 m, 201-500 m, and 501-800 m. However, biologically relevant strata resulting from the a posteriori community analysis made here do not coincide with the MEDITS strata. It is therefore clear that characterisation of the biotic assemblages is important in order to have a better sampling representation of each biologically meaningful depth-zone/assemblage type, and this should be incorporated into the survey designs.

Furthermore, assemblages determined a posteriori are also important in order to enable abundance estimation (e.g. density and biomass indices) and indicators (diversity indices and size spectra), assessment at a multispecies level (integrated also by environmental data) as requested by the precautionary and ecosystem based approach. Classic designs can be maintained to estimate abundance for single species but analysis of assemblages based on data gathered in the same surveys needs to be made to generate ecologically meaningful depth strata for the analysis of biotic communities. One also needs to take into consideration that a statistical design based on demersal assemblages in different countries in a large basin such as the Mediterranean Sea will result in a very heterogeneous sampling allocation and problems will emerge when comparing data across large distances such as the case for the Mediterranean sea. Hence, a standard protocol for the collection of data aimed at allowing a comparison across large areas is more desirable; a post-stratification of sampling stations according to the assemblages identified can be used to improve local assessments and management advice. This may also apply to other trawl survey programmes implemented elsewhere outside the Mediterranean sea.

In general, the transition from one assemblage to the next is gradual at the shallower depths and becomes sharper as the depth increases. For instance, the dissimilarity between the Deep Slope assemblage and the shallower assemblages is the highest (e.g. dissimilarity between DS and OSA = 91.58); dissimilarity was lowest between the deeper assemblages (e.g. dissimilarity between DS and SL = 65.22). The differences between the shelf break, shallow slope and deep slope were mostly qualitative (table 3.2) since most of the species recorded in either one of the assemblage were not present in the other and this explains the high dissimilarity values obtained.

The main environmental variable that predicted the observed change in community structure over the depth range studied was depth. This has also been shown to be the case in other areas of the Mediterranean (Biagi *et al.*, 1989). Temperature is the second most important factor responsible for the zonation of the assemblages (most likely because there is a strict correlation between depth and temperature). Although the observed variation in temperature is very small (ca. 1°C) in the depth range studied, a slight variation in seawater temperature can have significant effects on the distribution of fish (e.g. Quéro *et al.*, 1998). Following these parameters sediment fractions became important including the percentage contribution of very coarse sand, coarse sand, and medium sand. Factors such as median grain size and organic carbon, which were expected to affect the structure of the assemblages, were found not to be important in this respect.

The ordination techniques and the analysis of similarities did not detect any temporal change in assemblage structure between the years under study, which is not unexpected since sampling was always conducted in the same month. A lack of temporal variation has also been found in other parts of the Mediterranean such as off the coasts of Tuscany in the Tyrrhenian Sea where assemblages persisted through time (Biagi *et al.*, 2002). This suggests that changes in assemblage composition are consistent over short time scales. Nonetheless, it should be noted that to track the temporal persistence of the deep water populations, a much longer series of data is necessary since changes in the deep sea may be very gradual and occur on a decadal scale. However, shorter term, sudden temporal changes may occur in areas exposed to chronic disturbances such as heavy trawling (Jennings *et al.*, 2001b).

Univariate community descriptors showed different trends with changes in depth. The total number of species, biomass, and abundance all decreased significantly with depth. In spite of this both evenness and diversity (H') did not decrease, suggesting that although secondary production in deeper waters is lower than in shallower waters, the habitat is still rich in species.

The analysis of assemblage structure has the potential to provide valuable inputs into fisheries management, particularly in multispecies fisheries such as the trawl fishery in the Mediterranean sea. Such analyses can assist in: (i) determining geographical or spatial boundaries of fish and other demersal assemblages, especially in relation to depth zonation; (ii) subdividing the fishery into components affected by different conditions, e.g. different intensities of fishing pressure, and to differences in environmental conditions; and (iii) designing management interventions applicable to different components of the fishery or to different areas, based on the spatial distribution patterns of the assemblages. This work has clearly shown consistent trends in community descriptors of the demersal assemblages, with a spatial partitioning of the assemblages present in all areas studied.

Based on the regional trends seen here, fisheries managers should request scientific advise on how assemblage structure and its relation to the depth ranges and fishing pressure could be used as a basis for revising existing fisheries zones and management units, as most of these are based on predetermined depth strata which may have no direct biological basis, may overlap different assemblages, and which do not take into account the assemblage structure. The identification of assemblages can be a very useful tool for making flexible management decisions especially in multi-species fisheries and would facilitate the implementation of management measures specific to the different assemblage types. In effect, geographical areas with distinct assemblages can be considered as different management units for the trawl fishery and this would be the first step towards an ecosystem approach in fisheries management.

Chapter 4

First evaluation of the ecosystem effects of fishing on the deep water (500 – 800 m) demersal resources of the Mediterranean.

This chapter will be submitted as a paper in the scientific journal Marine Ecology Progress Series as:

Dimech M, Kaiser MJ, Ragonese S, Schembri PJ. First evaluation of the ecosystem effects of fishing on the deep water (500 – 800 m) demersal resources of the Mediterranean.

4.1 Abstract

Fishing with demersal towed gears has dramatic effects on the structure and functioning of marine ecosystem including over-fishing, depletion of target and by-catch demersal resources, and stress on associated benthic populations and bottom habitats. The present work aimed to study the ecosystem effects of the Mediterranean deep sea red shrimp trawl fishery (500-800 m) in the Sicilian Channel, at the population and community level by sampling in trawled and non-trawled treatment sites as determined by the Vessel Monitoring System (VMS) fishing effort data for the year 2006 and 2007. The present study was conducted within the 25 Nautical Mile Fisheries Management Zone round the Maltese islands as part of the ongoing MEDITS trawl survey programme. Both population and community indicators were computed and compared across the trawled and non-trawled treatment sites. At the population level, *Aristaeomorpha foliacea* and *Etmopterux spinax* did not show any differences in biomass between the trawled and non-trawled treatment sites while the biomass of *Plesionika martia, Nephrops norvegicus, Helicolenus dactylopterus dactylopterus,* and *Galeus melastomus* was four, sixteen, six and two times higher, respectively, in the non-trawled sites. Changes in the length structure were also detected for all the species except *Etmopterux spinax.* At the community level, higher biomass, density and diversity indices were recorded in the non-trawled sites. Multivariate analysis gave two main groups of stations which corresponded to the trawled and non-trawled sites. Apart from the species studied at population level, other species like *Chlorophthalmus agassizi, Heptranchias perlo*, *Centrophorus granulosus*, *Merluccius merluccius* and *Phycis blennoides* were also responsible for the differences between the trawled and non-trawled sites. This study has provided evidence for the alteration of the ecosystem at population and community level on central Mediterranean muddy bottoms of the deep slope due to fishing, with the shrimps *A. foliacea* and *P. martia* showing a high resilience to trawling activities. The possibility of setting up trawling lanes as a management option to achieve sustainable exploitation of demersal resources with a minimal impact on species with slow growth rates and low resilience is discussed in light of the results of this study.

4.2 Introduction

Bottom-trawling has dramatic effects on the structure and functioning of marine ecosystems. These effects include physical damage to the seabed, degradation of associated benthic communities, over-fishing of demersal resources, the generation of by-catches and associated discards, and reduction in mean body size within the fish assemblage, which is associated with an increase in dominance by smaller body-sized species with a relative increase in smaller individuals (Beverton and Holt, 1957; Hall, 1999; Jennings *et al.*, 1999; Kaiser and De Groot, 2000). The effects of demersal fishing on marine communities are twofold: for individual species, the population dynamics of the population are altered, and at the community level profound changes occur because of the disruption of food webs and other effects brought about due to the changes in the population dynamics of individual species. Ecosystem modifications are triggered by the change in the biomass and demographic structure of the different species populations as well as by the diversion of energy within the system to scavenging and opportunistic species (Kaiser *et al* 1994; Ramsay *et al.*, 1998; Demestre *et al* 2000b).

The aggregate responses of populations and communities to fishing have been described using multivariate techniques (Kaiser *et al.*, 1998; Labropoulou and Papaconstantinou 2005), single indicators such as biomass and abundance indices (Ware, 2000; Rochet and Trenkel, 2003; Rochet *et al.*, 2005), biodiversity indices (Greenstreet and Hall, 1996; Merigot *et al.*, 2007), population indicators (Jennings *et al.*, 1999; Ceriola *et al* 2008), size spectra (Rice and Gislason, 1996; Dimech *et al* 2008), and trophic structure (Pauly *et al.*, 1998; Pinnegar *et al.*, 2002). Indicators of the effects of fishing on marine communities are required to support an Ecosystem Approach to Fisheries management (EAF) (Link, 2002; Rice, 2003). Many governments and regulatory bodies have already agreed to implement an EAF but, with the exception of indicators for commercially exploited fish stocks (Smith *et al.*, 1993; Garcia and Staples, 2000), the development and testing of indicators for communities and non-target species are not well advanced (Rochet and Trenkel, 2003; Piet and Jennings 2005).

Although a large number of studies have been conducted in northern European waters (Lindeboom and de Groot, 1998; Kaiser and De Groot, 2000), not all results may be relevant to the Mediterranean because this sea is markedly different due to its oligotrophic status, high salinity, high water temperatures (12 - 15°C below the thermo cline at ca. 50-100 m), microtidal nature, and extreme range of depth.

Bottom trawling is an important component of many Mediterranean fisheries and the seabed is trawled by commercial fishers at depths ranging from 50 m to 800 m (Papaconstantinou and Farrugio 2000; Lleonart., 2005). Trawl catches are composed of a highly diverse mix of fish (teleosts and elasmobranchs), cephalopods and crustaceans (decapods and stomatopods), together with several macroepibenthic invertebrates (Caddy, 1993; Relini *et al.*, 1999). One of the most important trawl fisheries in the Mediterranean is that for the deep-sea red shrimps (*Aristaeomorpha foliacea* and *Aristeus antennatus*) of the slope at depths from 500 – 800m (Caddy, 1993; Moranta *et al*, 2000).

In the Mediterranean there have been few studies undertaken to examine the effects of bottom trawling on demersal resources. This is largely due to the large depth range targeted by demersal fisheries and the stratification of demersal assemblages with increasing depths make it more difficult to address the effects of trawling. The few studies undertaken to date deal with the impact of trawling on the demersal ecosystems on the continental shelf system, (Sánchez 2000, Caddy 2000, Pipitone *et al* 2000, de Juan *et al*, 2006, Dimech *et al*, 2008), shelf break (Smith *et al.*, 2000, Gristina *et al.*, 2006,), and on the deep slope (Papaconstantinou and Kapiris 2003, D'Onghia, *et al*, 2005). Although there are also a number of studies on discards from trawling activities (Sartor *et al* 1999, Sanchez *et al* 2007) there are no studies to date which deal with the large scale effects of bottom trawling at the population and community levels for deep slope demersal resources of the Mediterranean. Some existing studies compare sites with relatively high and low fishing intensities but none provide quantitative data of the fishing effort in the sites compared. Furthermore, the deep water trawl fishery for red shrimps can be considered as 'mono-specific' (with either one of the two red shrimp species being dominant in the catch) relative to the trawl fisheries on the continental shelf and upper slope, since fishers target exclusively red shrimp. In addition, red shrimps are exclusively harvested by bottom otter trawls, whereas a variety of gears are used on the continental shelf and upper slope (Papaconstantinou and Farrugio 2000; Lleonart., 2005).

The aim of the present study was to quantify the ecosystem effects of the Mediterranean deep-sea (500-800 m) red shrimp trawl fishery by looking for responses in population and community structure and size spectra. The study also utilised a sampling design with known trawled and non-trawled treatment sites as determined by Vessel Monitoring System (VMS) fishing effort data

4.3 Sampling methodology

The present study was conducted within the 25 Nautical Mile Fisheries Management Zone around the Maltese islands. The study was part of the ongoing MEDITS trawl survey programme (Bertrand *et al.*, 2002). Otter trawl samples were collected by the RV *Sant'Anna* in July 2007 from 7 stations located in trawled sites and 7 stations from non-trawled sites (Fig. 4.1); one haul per station was made. The depth ranged between 517 m and 671 m with a mean depth of 616 m for the trawled sites and 556 m for the non-trawled sites. The difference between the mean depths was kept to a minimum to avoid the confounding effect of bathymetric changes in population and community structure. Areas trawled by the commercial fishery were identified using the Vessel Monitoring System (VMS) data for the year 2006 and 2007. Fishing effort for the trawlers operating in the areas was calculated from the VMS data after it was filtered by considering vessel speeds of between 2 – 4 knots to be indicative of trawling on the deep slope, since in the Mediterranean trawlers travel an average speed of 2-3 knots when trawling at such depths. Using GIS techniques to map the VMS data, it was then filtered by area identifying the trawling grounds within those depths, by deleting the VMS data points which occurred outside the trawled areas. Trawling effort for the deep slope trawling grounds was calculated as number of days fishing, Gross Tonnage multiplied by days (GT*days), and kilowatts multiplied by days (kW*days), for the years 2006 and 2007; the total swept area was ca. 100 km^2 (table 4.1). The trawling effort in the non-trawled areas was zero.

Table 4.1 Trawling effort estimates for the trawled areas

Year	No of trawlers	Total no of Fishing days	Total Effort (kW*days)	Total Effort (GT*days)
2006	8	523	205702	43503
2007	7	329	110187	23992

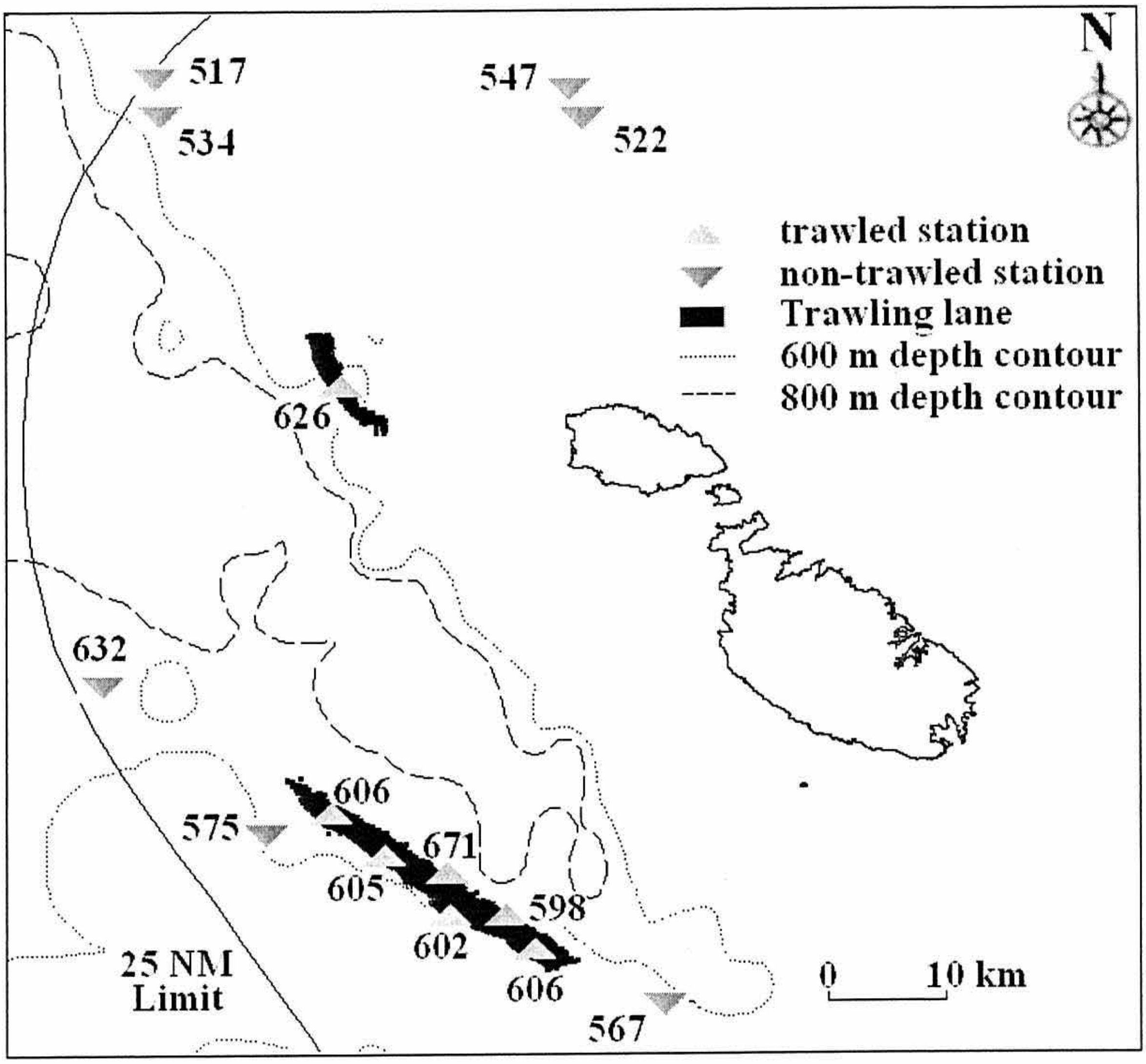

Figure 4.1 Map showing the sampling stations with their respective mean depths (m). The VMS was recorded every 2 hours and the data shown clearly indicates the trawling lanes.

Each sampling haul lasted for 45 - 60 minutes and trawl speed was ca. 3 knots. Samples were collected using a 20-22 m wide and 40 m long experimental otter trawl net with a 2-2.5 m vertical opening and a cod end stretched mesh size of 20 mm (IFREMER GOC 73) (Fiorentini *et al.*, 1999). Further survey specifications can be found in Anon. (2007). The entire biological component from each haul was sorted, after which the fauna were identified, weighed and counted. Biological parameters were also collected for the

MEDITS target species, including length, weight and sex (Bertrand *et al.*, 2002; Anon., 2007) and in addition, population parameters were collected for the pandalid shrimp *Plesionika martia* and all the elasmobranches.

4.3.1 Parameters analysed

We examined differences in population parameters for individual species (Table 4.2) as well as differences in assemblage characteristics between trawled and non-trawled treatment sites. The species selected for comparison of their response to trawled and non-trawled treatment sites varied in their life-history characteristics and habitat distribution (Table 4.2)

Table 4.2 Species selected for the analysis at the population level, with an indication of their ecological characteristics, commercial importance and maximum recorded length.

Species	Ecological characteristic	Commercial importance	Max recorded length in the Mediterranean
Aristaeomorpha foliacea	Opprortunistic	High	CL 70 mm (♀; Ragonese *et al.*, 1994).
Plesionika martia	Opprortunistic	Medium	CL 26 mm Maiorano *et al.* 2000
Nephrops norvegicus	Sedentary	High	CL 79 mm in (Mytilineou *et al.*, 1998)
Helicolenus dactylopterus dactylopterus	Sedentary	Medium	TL 36.1 cm (♂; Ribas *et al.*, 2006).
Galeus melastomus	Active predator and scavenging species	Low	TL 52 cm (♀; Serena 2005)
Etmopterux spinax	Active predator and scavenging species	No	TL 60 cm (Serena 2005)

The variables measured at the population level are listed in Table 4.3. The numbers of individuals per species and size class for each haul were standardized per km^2 and the length frequency distributions (LFD) for each species in the trawled and non-trawled treatment sites were plotted. Population status was assessed from length frequency data using the simple methods described by Froese and Binohlan (2000). The parameters estimated included the theoretical optimal size (L_{opt}) which is the length at which a cohort maximizes its production (maximum possible yield per recruit), the length at maturity (L_m) and the asymptotic length (L_∞) which is the mean length the animals of a given population would reach if they were to grow forever according the Von

Bertallanfy Growth Function (VBGF). L_{opt} was estimated using the VBGF parameters for *A. foliacea* (Ragonese *et al.*, 1994), *P. martia* (Maiorano *et al.*, 2000), *N. norvegicus* (Ragonese *et al.*, 2004) and *H. dactylopterus dactylopterus* (Ragonese *et al.*, 2004), while for *G. melastomus* and *E. spinax* it was estimated from L_∞ (Froese and Binohlan 2000) since no growth parameters were found for these two species (Fishbase). The optimal (L_{opt}) and the maturity (L_m) lengths were superimposed onto the LFD plots and the percentages of the number of individuals less than L_m and L_{opt} were calculated for the trawled and non-trawled treatment sites.

4.3.2 Community level

The total abundance (density - DI, and biomass - BI) indexes for each station, standardised per square kilometre, were computed for fish, crustaceans and cephalopods. Only the biomass data were used for further community analysis since these yield more clearly interpretable results (Dimech *et al* 2008). The BI for each station was analysed using multivariate classification and ordination techniques. A similarity matrix was constructed from the fourth-root transformed data using the Bray-Curtis similarity measure, following which agglomerative hierarchical clustering and non-metric multidimensional scaling (nMDS) ordination were applied (Clarke and Warwick 2001a). The SIMPER procedure was used to determine which species contributed most to the dissimilarity between the trawled and non-trawled stations (Clarke and Warwick, 1994). The Analysis of Similarities (ANOSIM) routine was used to test for differences between the two sites. The PRIMER 6 software package was used to undertake the statistical analyses (Clarke and Warwick 2001a).

Biodiversity indicators and other univariate parameters (table 4.3) were calculated for each station to test the utility of each indicator to detect differences between the trawled and non-trawled treatment sites. Taxonomic diversity indices were also calculated (table 3) since these take into account the functional differences between species (Clarke and Warwick 1998, 2001b). The taxonomic diversity indices were computed based on the suggestions and methods described in Merigot *et al* (2007) for the Mediterranean. However, we included all species for the calculation of the taxonomic diversity indices, rather than only the ground fish (as in Merigot *et al* 2007). This was done for two reasons, firstly to be able to compare the results of the taxonomic diversity indices with the other biodiversity indices, and secondly because the deep slope is also characterised by a strong component of decapod species (Dimech *et al.*, 2008).

Size spectra were also calculated for the trawled and non-trawled treatment sites using the weights of individuals from all taxonomic groups, including teleosts, chondrichthyes, crustaceans and cephalopods. Since different hauls did not sweep equal areas of the bottom, weights were standardized per km^2, after which each individual was assigned to a weight-class ($\log_{10}$ weight in grammes). The data were normalised and the logarithm of the biomass was calculated. Lower and upper size classes were excluded to avoid data artefacts due to poor retention in the gear (Duplisea *et al.,* 1997; Jennings *et al.,* 2001).

Differences between the univariate parameters calculated both at the population and community level were analysed using a non-parametric two independent sample Mann-Whitney U test.

Table 4.3 Population and community level variables analysed for the trawled and non-trawled areas sampled

Definition of indicator	Population	Community	Expected effects of fishing
$\overline{BI}$ - Mean biomass index (kg/km^2)	X		Decrease
$\overline{DI}$ - Mean density index (N/km^2).	X		Decrease
$\overline{W}$ - Mean individual weight (g)	X		Decrease
$\overline{TL}$ or $\overline{CL}$ - Mean individual length	X		Decrease
$\overline{L}_{max}$ - Mean maximum length per treatment	X		Decrease
L_{max} - Recorded maximum length	X		Decrease
L_{opt} - Theoretical optimal size	X		N/A
L_m - Length at maturity	X		N/A
L_{∞} Asymptotic length	X		N/A
$\overline{BI_t}$ - Mean total biomass index (kg/km^2)		X	Decrease
$\overline{BI}_{teleosts}$ - Mean teleosts biomass index (kg/km^2)		X	Decrease
$\overline{BI}_{chondrichthyes}$ - Mean chondrichthyes biomass index (kg/km^2)		X	Decrease
$\overline{BI}_{decapods}$ - Mean decapods biomass index (kg/km^2)		X	Decrease
$\overline{DI_t}$ - Mean total density index (N/km^2)		X	Decrease
$\overline{DI}_{teleosts}$ - Mean teleosts density index (N/km^2)		X	Decrease
$\overline{DI}_{chondrichthyes}$ - Mean chondrichthyes density index (N/km^2)		X	Decrease
$\overline{DI}_{decapods}$ - Mean decapods density index (N/km^2)		X	Decrease
$\overline{S}$ - Mean total number of species		X	Decrease
$\overline{1-\lambda}$ - Mean Simpson diversity index		X	Decrease
$\overline{D}$ - Mean Margalef Species richness		X	Decrease
$\overline{H'}$ - Mean Shannon-Weiner diversity index ($\log_e$)		X	Decrease
$\overline{J'}$ - Mean Pielous evenness		X	Decrease
$\overline{\Delta}$ - Mean Taxonomic diversity index		X	Decrease
$\overline{\Delta^*}$ - Mean Taxonomic distinctiveness index		X	Decrease
$\overline{\Lambda^+}$ - Mean Variation in taxonomic distinctness VarTD		X	Decrease

4.4 Results

4.4.1 Population level

A total of 1191 and 2608 individuals were caught from the trawled and non-trawled treatment sites respectively. The number per species is given in figure 4.2. The red shrimp *Aristaeomorpha foliacea* was the most dominant in terms of abundance (DI) and *Galeus melastomus* in terms of total weight (BI). A comparison of the size-class frequency distributions for individual species sampled in the trawled and non-trawled treatment sites revealed similarities in the frequency distribution of individuals among size-classes, however, the number of individuals in each size class was clearly much lower in the trawled sites compared with the non-trawled sites (Fig. 4.2).

Aristaeomorpha foliacea

Both the BI and DI indices were not significantly different (Mann-Whitney U $p<0.05$; table 4.4) between the trawled and non-trawled treatment sites. However, from the length frequency distribution (LFD) analysis it is clear that a larger number of recruits (females; CL 27-33 mm) are present in the non-trawled sites, whereas larger individuals (females; CL 54-63 mm) are more prevalent in the trawled sites (Fig 4.2). In fact, the mean carapace length (CL, mm) and mean individual weight were significantly higher in the trawled sites (Mann-Whitney U $p<0.05$; table 4.4) while the mean maximum CL was not significantly different. The LFD analysis showed that 51% and 75% of the individuals are less than L_m and 85% and 97% are less than L_{opt} in the trawled and non-trawled sites respectively. These values are relatively high when one considers that a portion of the population are males (mostly between CL 36-46 mm), which mature at about CL 30-33 mm (Ragonese *et al.*, 2004). However, the percentage of individuals recorded below the L_{opt} for the trawled sites are much lower than that of the non-trawled sites, indicating higher fishing activities at the trawled sites with recruitment overfishing.

Plesionika martia

The BI and DI indices were significantly higher (Mann-Whitney U $p<0.05$; table 4.4) and almost four times higher in the non-trawled compared with the trawled sites. However mean CL was not significantly different, but a higher mean individual weight was recorded in the trawled sites (Mann-Whitney U $p<0.05$). The LFD was very similar in the two sites except for the higher number of juveniles and adults in the non-trawled sites. The LFD analysis indicated an apparently healthy, lightly fished population with most individuals above the size at first maturity and within the range of L_{opt}.

Nephrops norvegicus

The BI and DI indices were nearly 16 times higher (Mann-Whitney U $p<0.05$; table 4.4) in the non-trawled sites compared to the trawled sites. However mean CL and mean individual weight were not significantly different (Mann-Whitney U $p<0.05$; table 4.4). The LFD is very different between the two treatment sites investigated with a larger proportion of *N. norvegicus* in the higher size classes in the non-trawled sites, with a significantly higher mean maximum CL (Mann-Whitney U $p<0.05$; table 4.4). The LFD analysis indicated that 27% and 12% of the individuals are less than L_m and 62% and 59% are less than L_{opt} in the trawled and non-trawled treatment sites respectively. Although a greater number of individuals less than the length at first maturity (L_m) were recorded in the trawled sites, and the populations in both sites have more than 40% of the individuals higher than L_{opt}, the *N. norvegicus* population in the trawled sites seem to be overexploited due to the occurrence of a biomass which is 16 times higher in the non-trawled sites (where the population is clearly unexploited).

Helicolenus dactylopterus dactylopterus

The BI and DI indices were significantly higher (Mann-Whitney U $p<0.05$; table 4.4) and almost six times as much in the non-trawled sites than in the trawled ones. However, mean TL and mean individual weight were not significantly different (Mann-Whitney U $p<0.05$; table 4.4). The LFD showed a high number of individuals in the larger size classes (TL 26-36 cm) but mean maximum TL was not significantly different (Mann-Whitney U $p<0.05$; table 4.4). The LFD analysis has shown that 55% and 34% of the individuals are less than L_m and 79% and 42% are less than L_{opt} in the trawled and non-trawled sites respectively. These results suggest that there is overfishing in the trawled sites with healthy and unfished populations in the non-trawled sites.

Galeus melastomus

Although the biomass index (BI) was twice as high in the non-trawled sites this was not significantly different; however, the density index DI was significantly higher (Mann-Whitney U $p<0.05$; table 4.4) in the non-trawled sites (almost three times as much). Mean TL and mean individual weight were significantly higher (Mann-Whitney U $p<0.05$; table 4.4) in the trawled sites. The LFD showed a larger proportion of juvenile individuals (TL 24-30 cm) in the non-trawled sites. The LFD analysis showed that 27% and 64% of the individuals are less than L_m and 68% and 87% are less than L_{opt} in the trawled and non-trawled treatment sites respectively. These results clearly indicate a recruitment overfishing and unfished populations in the trawled and non-trawled sites respectively.

Etmopterus spinax

No significant differences in all the parameters measured were noted for this species. The LFD was dominated by individuals in the 22-32 cm size class in both treatment sites. The LFD analysis has shown an apparently healthy population with most species above the size at first maturity and many large specimens above the L_{opt} range. The populations do not seem to be fished at all.

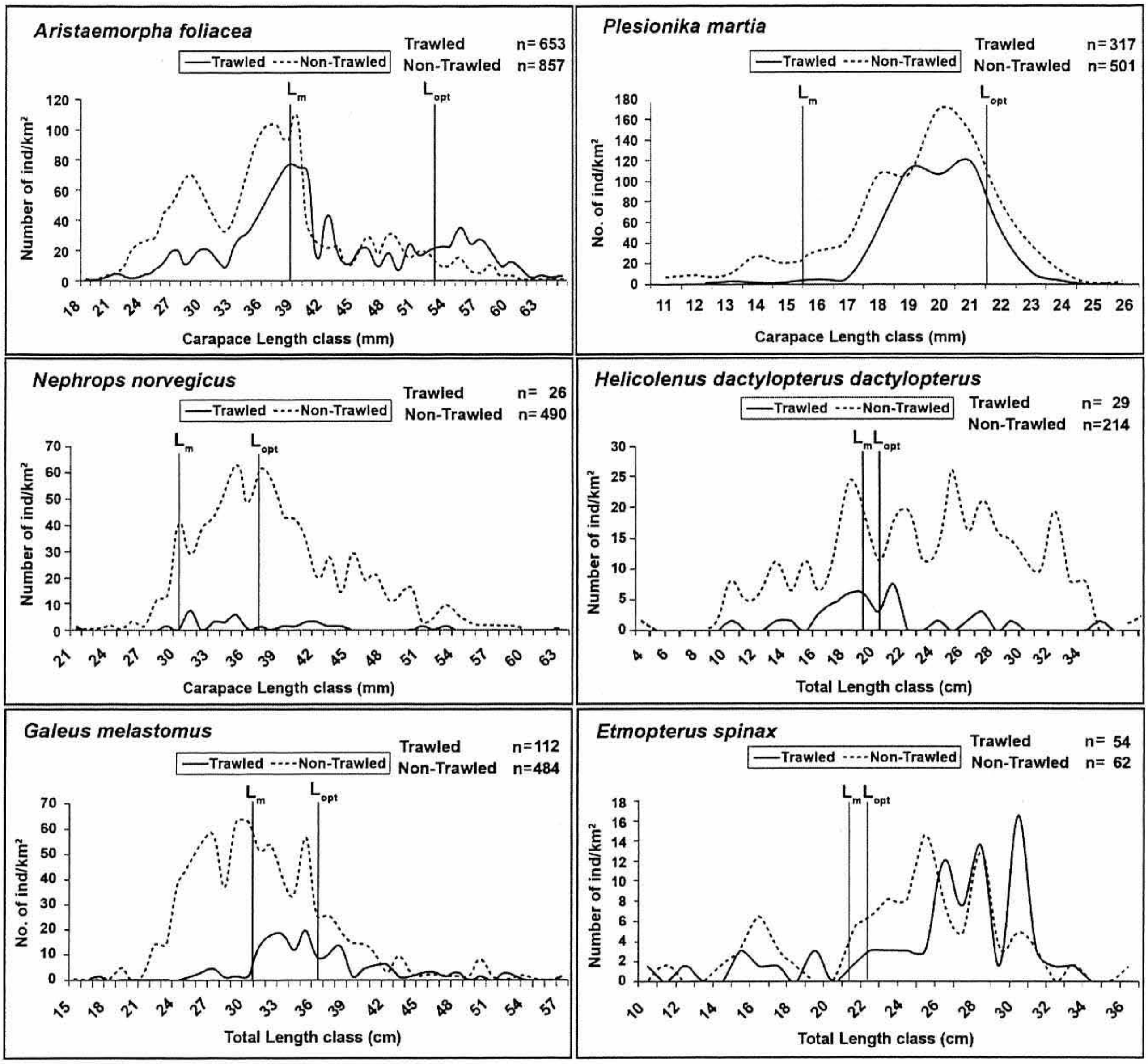

Figure 4.2 Length frequency distributions for *A. foliacea, P. martia, N. norvegicus, H. dactylopterus dactylopterus, G. melastomus*, and *E. spinax* in the trawled and non-trawled treatment sites.

Table 4.4 The mean values for biomass (kg/km^2) and density (N/km^2) indices, body length and weight and maximum length with ± standard deviation, together with the results of Mann-Whitney U analysis are also shown (bold figures show a significant difference).

	Trawled (±s.d.)		Mann-Whitney U	P value
	Y	**N**		
A. foliacea				
$\overline{BI}$ (kg/km^2)	26.3 ±5.5	28.5 ±21.9	24	0.949
$\overline{DI}$ (N/km^2)	979 +296	1534+1037	17	0.338
$\overline{W}$ (g)	28.21+6.62	17.86+3.34	**3**	**0.006**
$\overline{CL}$ (mm)	42.19 ±3.5	35.95±2.67	**2**	**0.004**
$\overline{L}_{max}$ (mm)	61.00±3.7	56.57 ±3.95	10	0.053
L_{max} (mm)	65.00	60.00		
P. martia				
$\overline{BI}$ (kg/km^2)	3.4 ±2.0	11.3± 7.1	**8**	**0.035**
$\overline{DI}$ (N/km^2)	606 ±374	2253 ±1307	**6**	**0.018**
$\overline{W}$ (g)	5.73 ±0.36	4.87 ±0.75	**5**	**0.037**
$\overline{CL}$ (mm)	19.91 ±0.33	19.24 ±1.23	9	0.150
$\overline{L}_{max}$ (mm)	23.17 ±0.75	23.83 ±1.72	16	0.730
L_{max} (mm)	24.00	26.00		
N. norvegicus				
$\overline{BI}$ (kg/km^2)	1.9 ±2.8	33.7 ±35.5	**0**	**0.004**
$\overline{DI}$ (N/km^2)	46 ±63	749 ±811	**0**	**0.004**
$\overline{W}$ (g)	40.76 ±23.2	45.64 ±9.91	12	0.372
$\overline{CL}$ (mm)	36.50 ±7.01	38.46 ±2.42	11	0.291
$\overline{L}_{max}$ (mm)	41.00 ±10.49	55.00 ±5.57	**19**	**0.030**
L_{max} (mm)	53.00	63.00		
H. dactylopterus				
$\overline{BI}$ (kg/km^2)	8.2 ±13.5	72.8 ±81.2	**7**	**0.046**
$\overline{DI}$ (N/km^2)	51 ±63	378 ±319	**3**	**0.010**
$\overline{W}$ (g)	119.4 ±55.1	139.6±82.5	18	0.668
$\overline{TL}$ (cm)	18.9 ±2.6	18.7 ±4.7	19	0.775
$\overline{L}_{max}$ (cm)	22.4 ±7.1	28.0 ±7.7	34	0.250
L_{max} (cm)	35.2	37.0		
G. melastomus				
$\overline{BI}$ (kg/km^2)	40.9 ±45.1	84.8 ±57.4	12	0.110
$\overline{DI}$ (N/km^2)	169 ±156	716 ±423	**5**	**0.013**
$\overline{W}$ (g)	252.1 ±128	120.5 ±38.9	**7**	**0.025**
$\overline{TL}$ (cm)	37.5 ±4.6	31.7 ±3.6	**7**	**0.025**
$\overline{L}_{max}$ (cm)	48.0 ±6.8	46.4 ±5.9	50	0.701
L_{max} (cm)	57.0	54.0		
E. spinax				
$\overline{BI}$ (kg/km^2)	7.5 ±4.82	13.2 ±12.62	16	0.475
$\overline{DI}$ (N/km^2)	81 ±70.8	149 ±158.7	16	0.475
$\overline{W}$ (g)	141.1 ±96.1	96.4 ±32.9	15	0.391
$\overline{TL}$ (cm)	26.3 ±2.9	25.4 ±2.8	18	0.668
$\overline{L}_{max}$ (cm)	29.8 ±2.2	31.1 ±2.9	46	0.614
L_{max} (cm)	33.0	36.0		

4.4.2 Community level

A total of 74 species (10 cephalopods, 17 decapods, 11 chondrichthyes and 36 teleosts) were identified; teleosts were the dominant taxon both in terms of BI and DI in the non-trawled sites, mainly due to the small bathydemersal fish *Chlorophthalmus agassizi*. In the trawled sites chondrichthyes were dominant in terms of BI and decapods in terms of DI, mainly due to the black mouth catshark *Galeus melastomus* in the former case and, the penaeid shrimp *Aristaeomorpha foliacea* and the pandalid shrimp *Plesionika martia* in the latter.

The BI and DI indices for all the taxonomic groups examined were significantly higher in the non-trawled sites (Mann-Whitney U $p<0.05$; Table 4.5) with overall biomass (BI) more than 4 times and number of individuals (DI) more than 6 times as much as in the trawled sites. With respect to the biodiversity measures, all the indices were significantly different between the trawled and non-trawled sites except for the Margalef species richness (D). The taxonomic diversity indices surprisingly gave different results from the more classical diversity indices with no significance differences for taxonomic diversity (Δ) and variation in taxonomic distinctness (Λ^+). Taxonomic distinctness (Δ^*) was significantly higher in the trawled sites.

Table 4.5 Results of the Mann-Whitney U test for community indicators between the trawled and non-trawled treatement sites.

	Trawled (±s.d.)		Mann-Whitney U	P value
Variable	**Y**	**N**		
$\overline{BI}_t$	157.9 ±99.6	704.0 ±269.5	0	**0.002**
$\overline{BI}_{teleosts}$	38.5 ±14.1	80.4 ±39.8	0	**0.009**
$\overline{BI}_{chondrichthyes}$	84.2 ±77.9	263.2 ±149.4	7	**0.025**
$\overline{BI}_{decapods}$	30.7 ±26.7	355.1 ±187.5	4	**0.002**
$\overline{DI}_t$	3,032 ±949	20,041 ±9089	0	**0.002**
$\overline{DI}_{teleosts}$	1,772 ±612	5,376 ±2115	0	**0.002**
$\overline{DI}_{chondrichthyes}$	269 ±209	1,013 ±602	4	**0.009**
$\overline{DI}_{decapods}$	990 ±454	13,556 ±9085	0	**0.002**
$\overline{S}$	21.00 ±2.08	27.14 ±4.18	1	**0.002**
$\overline{1-\lambda}$	0.80 ±0.02	0.85 ±0.08	7	**0.025**
$\overline{D}$	4.08 ±0.31	4.04 ±0.71	19	0.482
$\overline{H'}$	1.98 ±0.13	2.39 ±0.23	5	**0.013**
$\overline{J'}$	0.65 ±0.03	0.73 ±0.08	7	**0.025**
$\overline{\Delta}$	61.71 ±4.19	58.82 ±6.36	9	0.227
$\overline{\Delta^*}$	77.30 ±5.82	69.49 ±2.83	4	**0.013**
$\overline{\Lambda^+}$	750.34 ±97.56	678.67 ±68.01	13	0.225

Higher intercepts were recorded in the biomass size-spectra for the non-trawled sites for all the taxonomic groups examined, reflecting the higher biomass detected in the non-trawled sites with the previous analysis (Fig. 4.3). The gradients are also quite similar except for teleosts which have a steeper negative gradient in the non-trawled site (-0.2518 vs -0.1773) due to the relatively higher proportion of smaller sized species (*Helicolenus dactylopterus dactylopterus* and *Merluccius merluccius*) in the community.

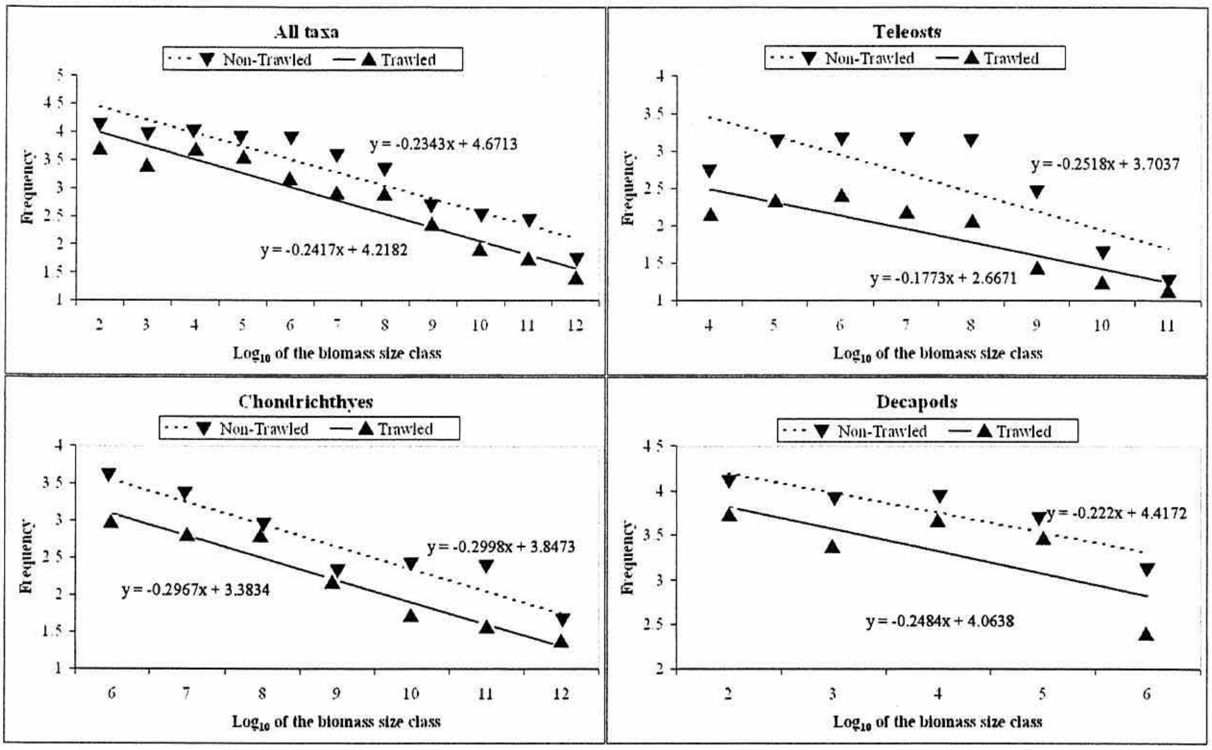

Fig 4.3. Biomass size-spectra for the different taxonomic groups in the trawled and non-trawled sites.

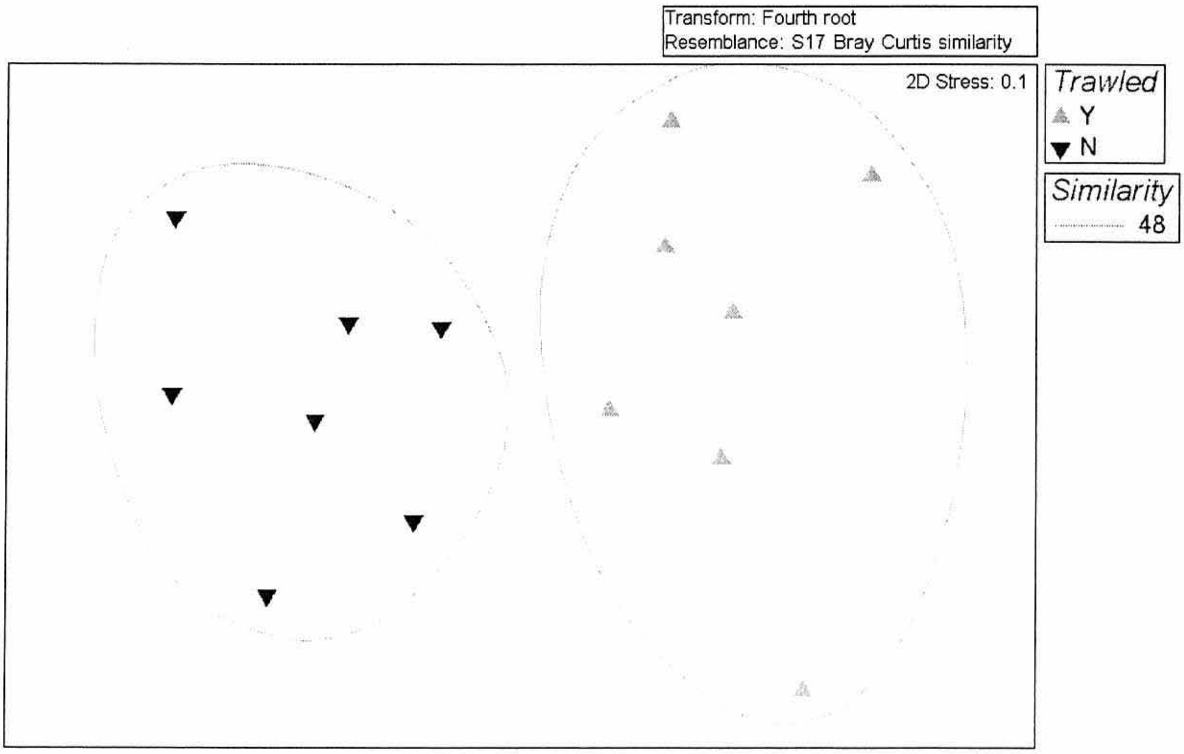

Figure 4.4 Non-metric multidimensional scaling (nMDS) plot for the sampling stations based on the biomass data (BI). The ovals show the groups generated by cluster analysis.

When classified on the basis of BI the multivariate analysis gave two main groups at a similarity of 48% (Fig 4.4). These groups represented the trawled and non-trawled stations. The species responsible for the difference in the community structure between the trawled and non-trawled sites were determined using the SIMPER routine which showed that a large number of species contributed to the dissimilarity between the two groups identified (Table 4.6), with higher mean biomasses for all the species in the non-trawled sites. Species other than the ones mentioned earlier, like the demersal sharks *Heptranchias perlo* and *Centrophorus granulosus* and commercial species like *Merluccius merluccius* and *Phycis blennoides*, were responsible for the higher BI indices in the non-trawled sites (Table 4.6). It is worth noting that certain elasmobranchs, including *Scyliorhinus canicula*, *Raja oxyrhinchus*, and particularly *Centrophorus uyato*, which is a very rare species in the Mediterranean (Serena 2005), were only recorded in the non-trawled sites (Table 4.6). Analysis of similarities (ANOSIM) showed that the groups identified by the multivariate techniques were also significantly different ($R= 0.728$, $P< 0.05$).

4.5 Discussion

4.5.1 Population structure

The length-frequency distribution of the red shrimp *A. foliacea* showed a high proportion of individuals in the 33-42 mm carapace length range in both trawled and non-trawled treatment sites, mainly due to males. The differences between the two sites was in the higher number of individuals in the 24-33 mm size class in the non-trawled site and higher numbers in the 54-63 mm classes in the trawled sites which are mainly females in both size ranges. The difference may be attributed to a larger mortality of juvenile females (24-33 mm) in the trawled site most likely as a consequence of the full retention by the commercial fishing cod ends (Ragonese *et al.* 1994). *A. foliacea* is an opportunistic species and seems to be an active predator and scavenger (Bello and Pipitone 2002; Chartosia *et al.*, 2005). The greater number of large females (54-63 mm) in the trawled sites may be due to migration of large individuals to the trawling lane due to the increased food supply likely enhanced by the increased mortality of organisms due to the trawling activities. The larger individuals of *A. foliacea* seem to prefer the trawled sites. However, depth may also be a factor since the non-trawled sites were at a slightly lower depth, with an average difference of ca. 60 m. This species appears quite resilient to trawling pressure as no overall differences in biomass were detected between the two treatment sites. However, a slight recent worsening of the stock in the Strait of Sicily was detected by Bianchini *et al.* (2003). The finding of the LFD analysis can be explained considering the basic features of the bottom trawling fleet which uses very fine mesh sizes in their cod-end and consequently the size at first capture is almost coincident with the size of recruitment. The resulting growth overfishing is compensated by a continuous supply of recruits and the high growth rates, shown in the first year of life.

Table 4.6 Species which contributed to 90% of the similarity as determined by the SIMPER procedure.

	Trawled		Mean dissimilarity = 77.87			
	Y	N				
Species	**Mean BI (kg/km^2)**	**Mean BI (kg/km^2)**	**Mean Diss.**	**Diss/SD**	**Contribution (%)**	**Cumulative (%)**
Chlorophthalmus agassizi	0.24	142.46	16.84	1.22	21.62	21.62
Galeus melastomus	40.88	84.82	8.33	1.25	10.69	32.31
Helicolenus dactylopterus dactylopterus	7.03	72.75	7.01	1.06	9.00	41.31
Heptranchias perlo	15.12	50.49	5.52	1.16	7.09	48.41
Centrophorus granulosus	9.72	46.44	5.24	0.71	6.73	55.13
Nephrops norvegicus	1.40	33.77	3.39	1.45	4.35	59.48
Merluccius merluccius	1.08	27.44	3.09	2.11	3.96	63.45
Hoplostethus mediterraneus	1.58	28.08	2.73	1.01	3.51	66.95
Aristaeomorpha foliacea	26.32	28.48	1.97	1.44	2.53	69.48
Phycis blennoides	3.56	14.87	1.93	0.93	2.47	71.95
Scyliorhinus canicula	0	18.53	1.90	1.12	2.45	74.40
Raja oxyrinchus	0	13.68	1.67	0.82	2.15	76.54
Centrophorus uyato	0	17.93	1.66	0.40	2.13	78.67
Nezumia sclerorhynchus	3.00	14.46	1.59	0.95	2.05	80.72
Chimaera monstrosa	1.70	10.92	1.23	1.15	1.57	82.29
Coelorhynchus coelorhynchus	1.18	10.15	1.18	1.40	1.51	83.81
Etmopterus spinax	7.51	11.29	1.17	0.96	1.50	85.30
Plesionika martia	3.37	11.25	1.10	1.47	1.42	86.72
Dalatias licha	9.21	0	0.91	0.39	1.17	87.89
Gadiculus argenteus	0	7.01	0.85	0.89	1.09	88.98
Todarodes sagittatus	4.47	3.91	0.76	0.84	0.98	89.96
Hymenocephalus italicus	1.27	5.57	0.74	0.75	0.96	90.92

Previous studies on the population structure of *A. foliacea* in areas with different levels of fishing pressure elsewhere in the Mediterranean identified a maximum CL 62 mm which is less than that recorded in this study (Max CL 65 mm trawled; Max CL 60 mm non-trawled) (Papaconstantinou and, Kapiris 2003), however in the Sicily channel, despite the intensive fishing of the species since the early eighties, Ragonese *et al.* (1994) reported a relatively a high number of large-sized shrimps.

With respect to *P. martia*, no differences were noted in the LFD except for higher numbers in the non-trawled site. This may indicate a resilience of the species to trawling due to its reproductive capacity, small size and fast population growth (Company and Sardà 1997). However, since both shrimps are not strictly benthonic but bentho-pelagic, migration from the trawled and non-trawled treatment sites may be the reason for the lack of difference. Scavenging species have been documented to aggregate in trawled areas (Kaiser *et al* 1994; Ramsay *et al.*, 1998). Red shrimp have been shown to migrate over large distances (Sardá *et al.*, 1997, Relini *et al.*, 2000) and migration may also be an explanation since the trawled and non-trawled treatment sites are relatively close to each other. The current fishing activity seems to be at the optimum for this species.

For *N. norvegicus* and *H. dactylopterus dactylopterus* the main difference was in the larger number of individuals (16 and 6 times higher respectively) in the non-trawled sites. Both species are considered as sedentary benthonic species, with *N. norvegicus* living in muddy burrows and *H dactylopterus dactylopterus* is classified as a sit-and-wait predator (Uiblein *et al.* 2003); both species have limited migration. However some migration from the non-trawled surrounding areas to the trawled site might still occur since most of the size classes were recorded in both treatment sites. Migration might be due to scavenging activity. In fact for *H dactylopterus dactylopterus* no significant difference was detected between the maximum TL in trawled and non-trawled areas. The LFD for the non-trawled areas also shows a better structured population and this has also been recorded in the western Mediterranean for areas with low fishing pressure (Ribas *et al.*, 2006). The lack of individuals in the 10-18 cm size class may be due to the sampling depth since this size fraction is more common at depths lower than 500 m (Massuti *et al* 2001; Ribas *et al* 2006). However, a significant difference was detected for the max CL for *N. norvegicus* but this may be a sampling artifact as a low number of specimens were recorded in the trawled sites. The LFD analysis has shown that the current level of fishing activity has led to the overexploitation of both *H. dactylopterus dactylopterus* and *N. norvegicus*.

The other two species investigated are sharks which are opportunistic feeders with documented scavenging activity (Cortés, E., 1999). For *G. melastomus* BI was double and DI was four times as much in non-trawled sites than in the trawled mostly due to the higher number of individuals in the 22-32 cm size class range. This may imply a higher fishing mortality of juveniles in the trawled sites and especially as a consequence of eggs destruction and displacement, with a recruitment overexploitation. Furthermore large individuals of *G. melastomus* were more common in the trawled sites with a significantly higher TL. This may be due to the increase in scavenging activity of the species since adults which live also in deeper waters are able to make large displacements in response to food availability (Jones *et al.*, 2003). For *E. spinax*, no major differences were detected except for a larger number of individuals of the 30-32 cm size class range in the non-trawled sites. This may be due to the high tolerance of the species to trawling.

Overall, the populations analysed indicate negative effects on relatively sedentary species like *N. norvegicus* and *H. dactylopterus dactylopterus* and high resilience to fishing by fast growing decapod species (*P. martia* and *A. foliacea*). Scavenging species like *G. melastomus* seem to be moderately affected while *E. spinax* was not affected at all. An in-depth analysis of the populations is beyond the aim of the present study; however, various pieces of evidence suggest that present levels of recruitment for the populations in the trawled areas are maintained by populations in areas protected from trawling (which is likely to represent the highest cause of mortality in the first age-groups of Mediterranean bottom-dwelling fishes and shrimps), both natural protected areas such as the rough bottoms and deep water coral reefs surrounding Malta (Schembri *et al.*, 2007), and legally protected areas such as the FAD fishery grounds (Pace *et al.*, 2007), World War II ammunition dumping sites and wrecks (pers. observation).

4.5.2 Community level

The changes in community structure brought about by otter trawling in the deep slope community are evident, species like *Chlorophthalmus agassizi*, were almost non existent in the trawled sites. The multivariate analysis clearly showed the difference between the two types of treatment sites. The classical biodiversity indices showed that overall diversity and evenness was higher in the non-trawled sites but contrasting results were obtained using the taxonomic diversity indices. The taxonomic diversity Δ gives the average distance on the taxonomic tree between every pair of individuals and which can be seen as a generalization of the Simpson's diversity index incorporating an element of taxonomic relatedness (Warwick and Clarke 1998). Although Δ and $1-\lambda$ are considered as complimentary, they gave different results. Taxonomic distinctness Δ^* considers individuals which only belong to different species and is an index with a function of pure taxonomic relatedness of individuals. (Warwick and Clarke 1998) and in this study it was significantly higher in the trawled areas. These results are in contrast with other studies using taxonomic diversity indices in the Mediterranean (Gristina *et al.*, 2006), which showed that taxonomic diversity indices are more sensitive to fishing pressure.

The trawl lane stations had a significantly lower number of species and lower abundance and biomass. Long lived species like *H. dactylopterus dactylopterus* were more abundant both in terms of DI and BI in the non-trawled sites. Changes in communities to ones dominated by small and fast growth opportunists has been observed as a general trend of community response to trawling disturbance (Lindeboom and de Groot, 1998; Thrush and Dayton 2002). The alteration of population structure of *N. norvegicus* and *H. dactylopterus dactylopterus* observed in the present study is consistent with the effect of trawling, as also indicated by the change in community structure, dominance of small and more resilient fauna (*A. foliacea* and *P. martia*), and the subsequent generation of more homogeneous ecosystems (Thrush and Dayton, 2002). Species of chondrichthyes which have a typically slow population growth as in *Heptranchias perlo, Centrophorus granulosus*, *Centrophorus uyato* and *Chimaera monstrosa* were common in the non-trawled sites but rare in the trawled sites. Although *Raja clavata* was only recorded in the trawled sites this may be due to bathymetric distribution since the species was sampled at the limits of its bathymetric distribution. Small-sized fishes like *Chlorophthalmus agassizi* (max TL 40 cm), *Hoplosteutus mediterraneus* (max TL

42cm), *Nezumia sclerorhynchus* (max TL 36 cm) *Coelorinchus coelorhincus* (max TL 48cm) and *Gadiculus argenteus* (Max TL 15cm) were also more common in the non-trawled sites. The trawling activities are not only having an impact on the large individuals but even on the small-sized fish which is contrary to what was recorded in other areas (Rice and Gislason, 1996; Jennings *et al.*, 1999). However, this was not evident in the size spectra analysis probably due to the presence of a larger number of overall small-sized juvenile fishes and decapod individuals in the trawled sites.

Trawling can result in large-scale ecological effects including the degradation of communities, over-fishing of demersal resources and depletion of populations (Hall, 1999; Kaiser and De Groot, 2000). New trawling sites in the Mediterranean and especially trawling grounds for decapod shrimps are known to be trawled repetitively before the commercial operation starts fully exploiting the demersal resources. Fishers argue that "cleaning a site is beneficial to the capture of red shrimps since trawling activities remove all the non-commercial catch and gives a better yield of shrimps" which in their view lay 'underneath' the non-commercial catch. The trawling activities and changes in catches described by the fishers have been demonstrated by the results in this study where the ecology of the deep slope is altered to favour opportunistic species like red shrimp. Furthermore, since trawling activities reduce species richness, abundance and biomass, fewer amounts of non-commercial species are brought up with each haul and hence less time is wasted in sorting the catch into target and non-target species. Apparently repeated trawling also favours the production of larger individuals of red shrimp as shown by the LFD.

4.5.3 Management implications

This study has provided evidence for an alteration of the deep slope populations and communities of the Mediterranean muddy bottoms due to fishing. However the main target species have shown high resilience to the trawling activities. Bottom trawling is responsible for a high share in total demersal catches worldwide (Caddy, 1993) and due to the increasing demand in fisheries products this industry is bound to last for a large number of years if not indefinitely. In order to have a sustainable exploitation of resources with minimal ecological impacts and in line with the ecosystem approach to fisheries management, trawling lanes could be established to enable harvesting of resources in a sustainable way. The setting up of trawling lanes will ensure a continuous supply of demersal fisheries resources. The trawled lanes in this study have constant trawling activities throughout the year, and fishing occurs when the weather permits. Only trawlers <24 m are allowed to fish in these areas. Fishers also keep their fishing restricted to the trawling lane since it yields good catches of red shrimps and the lane is relatively free from obstructions which may damage the net, such as limestone slabs used in the FAD fishery which cover the entire seabed round the islands (Pace *et al* 2007). The impact of the trawling activities is limited to the trawling lanes thus minimising the impacts on species with slow growth and low resilience. This also ensures high catches as the non-trawled areas surrounding the trawling lanes act as refugia which supply the trawling lanes with a constant influx of individuals, which may then be harvested. Fisheries managers should examine the possibility of introducing trawling lanes in specific areas in such a manner and quantity as not to affect the fishery negatively. This will also ensure that trawling activities are not conducted everywhere on the seabed and thus minimising the impacts of trawling to the trawling lanes. Fishers will tend to move to new un-fished areas as catches in terms of biomass will always be high in non-trawled areas (as has been shown in this study), but the setting up of trawling lanes may be one solution to partially reduce the negative impacts of trawling on the demersal ecosystems. However this may only be possible in waters under national jurisdiction where fisheries managers have control. The situation will be different in waters outside national jurisdiction and on the high seas were the management of the open access resources will be much more difficult since it then falls within the remit of the regional fisheries management organisations which will have a daunting task to enforce this management measure.

Chapter 5

Fishers' perception of a 35-year old Exclusive Fisheries Zone

This chapter was submitted and accepted as a paper in the scientific journal Biological Conservation as:

Dimech M, Darmanin M, Smith PI, Kaiser MJ, Schembri PJ. Fishers' perception of a 35-year old Exclusive Fisheries Zone. Biological Conservation (*in press*).

5.1 Abstract

Fishers' attitudes and perceptions are critical for the success of fisheries protection areas, and a failure to understand fishers' behaviour may undermine the success of such fisheries management measures. In this study, we examine fishers' perception of a long-established exclusive fisheries zone around Malta and to investigate if the perceptions depend on fishers' demographic, economic, social characteristics and fishing activity of the fishers. A questionnaire survey was undertaken to evaluate the demographic characteristics, economic situation (costs and revenue) and fishers' activity and behaviour, together with their perception of the management zone. A total of 241 interview responses were analysed which was a response rate of 60%. The perception of most fishers was that the establishment of the FMZ has had an overall negative impact on their fishing activity and that the zone is not important for the protection of local fish stocks. When asked about the beneficial effect of the zone for fishers, most fishers from all backgrounds said that the zone does not benefit commercial fishers, but benefits mainly recreational fishers. The most evident differences in the perceptions and attitudes were between the full-time, part-time and recreational fishers. Fishers that have been fishing for more than 35 years and fishers from the main fishing village also had different attitudes from other fishers towards the FMZ. The results of this study suggest that the proportion of individual income derived from fishing was the strongest factor that influenced attitudinal differences, with home port and fishing experience having less important effects. The main differences in attitude among fishers were related to the protection and conservation effects of the zone, enhancement of resources and conflicts among user groups. The heterogeneity among fishers' attitudes revealed by the present study indicate that the implementation of spatial closures may gain inherent acceptance from some sectors of the industry, while others may require additional incentives to accept such schemes.

5.2 Introduction

Although many management tools exist to achieve the sustainable use of marine resources, a chronic failure to implement management recommendations or uncertainty in the science has led to well documented global declines in many fisheries (Pauly *et al.* 2002; Myers and Worm 2003). In this context, there is greater interest and application of the use of spatial restrictions to limit fishing effort (Agardy *et al.* 2003; Gell and Roberts 2003). The success of management systems that restrict access to marine resources, depends on the extent to which fishers are willing to comply with such systems (Jentoft & MacCay 1995; Jentoft *et al.* 1998; Zanetell & Knuth 2004; Richardson *et al.*, 2005). The attitude and behaviour of fishers has a critical influence on the likely success of fishery management measures and a failure to understand and manage fishers' behaviour has contributed to many fisheries problems (Hilborn 1985; Jentoft *et al.* 1998).

If fisheries management is to be successful, an understanding of perceptions and attitudes of fishers could help predict their likely response to current and new policy or management measures (McManus 1996; Hanna 2001). At present, the major insights to fishers' behaviour have come from standard economic and common property theory, which suggests that if fishers engage in rational economic behaviour, then the overexploitation of open-access resources is inevitable (Gordon 1954; Hardin 1968). An underlying assumption of these theories is that all fishers are motivated by the same desire for financial gain and engage in similar decision-making processes (Hanna & Smith 1993), although research shows that they are generally more heterogeneous in their motivation and behaviour than previously assumed (Hanna & Smith 1993; Jentoft & Davis 1993; Gelcich *et al.* 2005a, Richardson *et al.*, 2005).

For individuals the interaction between their attitudes and objectives that influence behaviour is reflected in the theory of reasoned action (Fishbein & Ajzen 1975; Ajzen 1988), which underpins much social and psychological work undertaken in recent years. This theory suggests that behaviour is best predicted by the intensions of a populace, which in turn are affected by the members' attitudes and the influences of significant others on their intentions to act. The person's attitude, combined with subjective norms, forms ones' "behaviour intention" (Fishbein & Ajzen 1975; Ajzen 1991). Alternative models, such as the transactional model of behaviour, propose that attitudes can also influence behaviour directly, and that these attitudes are affected by psychological and environmental variables (Bentler & Speckart 1979; Lazarus & Folkman 1984). These theories have been applied to the economic behaviour of a range of natural resource users, and results suggest that the personal and business characteristics significantly affect the attitudes and economic behaviours of farmers and fishers (Featherstone & Goodwin 1993; Filson 1993; Traoré *et al.* 1998; Willock *et al.* 1999; Austin *et al.* 2001; Jacobson *et al.* 2003). Specific studies on fishers indicate that their behaviour can be influenced by a combination of factors, including their attitudes (for example, regarding the legitimacy of the regulatory process), a social component (including moral values and peer pressure) and various demographic variables (Jentoft & Davis 1993; Hart 1998; Hatcher *et al.* 2000; Blyth *et al.* 2002; Eggert & Ellegard 2003; Flaaten & Heen 2005; Richardson *et al.* 2005).

Property rights may also be a major determinant of fishers' attitudes and behaviour (Hardin 1968; Blyth *et al.* 2002; Dalton *et al.* 2004; Janmaat 2005). Individuals respond to economic incentives, which in turn are influenced by the prevailing property rights structure (Furubotn & Pejovich 1972). Weak or absent property rights can create incentives for overexploitation and consequent resource depletion, while stronger rights, whether formally or informally granted, can incentivize resource conservation and stewardship as future returns are subject to protection (De Alessi 1998; Dalton *et al.* 2004). Research suggests that incentives for resource stewardship are influenced by factors such as the resource characteristics, resource user group characteristics, institutional arrangements and history (Wade 1988; Ostrom 1990; Baland & Platteau 1996; Agrawal 2001; Hanna 2001). Interestingly, in a study of a trawl fishery, Hanna and Smith (1993) found that many of their respondents had long-term plans and a vested interest in resource sustainability, while fishers' perceptions of management and problems associated with over-fishing varied among ports and age-groups. Similarly, Jentoft and Davis (1993) identified two distinct attitudinal approaches to fishing among small-boat fishers in Nova Scotia, which reflected fishers' ages, education and experiences. Other studies also suggest that attitudes to management vary between groups of fishers with different previous experiences of management (Gelcich *et al.* 2005a,b), or between groups using different types of fishing gears (Blyth *et al.* 2002). Richardson *et al.* (2005) concluded that fishers' attitudes are related to the fishery characteristics of the sector and its resource base, in particular, target species' mobility and past sector experiences predicted the inclination of fishers in each sector towards resource stewardship.

While fisheries scientists have devoted substantial effort to understanding the response of target species to fishing, the drivers that underpin fishers' behaviour in response to management measures remain poorly understood (Kaiser 2005). Designing institutions for resource management should take into account the characteristics of individual resource systems and users as these will critically affect success (Runolfsson 1997). The effectiveness of management will be severely compromised if fishers do not comply (for example Hanna & Smith 1993; Kaplan 1998). Even if fishers comply with the letter of the law, there may be unintended consequences of their efforts to maintain their income under restrictive regulations. Consequently, there is an urgent need to understand fishers' attitudes and the influences that act upon them, as this may further understanding of current behaviour as well as helping to predict likely responses to new management strategies.

Since 1971, Malta has managed fishing in a zone surrounding the Maltese archipelago extending to 25 nautical miles from baselines and covering an area of 11,980 km^2 (Fig. 1). The objective of the original Exclusive Fishing Zone (EFZ) was to protect the local artisanal fisheries by excluding foreign large-scale commercial fishing, especially trawling. After Malta became a member of the European Union (EU) in 2004, fishing in its waters became subject to the Common Fisheries Policy and fishing vessels from other EU member states gained access to Malta's waters beyond 12 nautical miles. However, in the interests of fishery conservation, the 25-nm zone was retained as a Fisheries Management Zone (FMZ) with limitations on fishing effort, vessel sizes and spatial restrictions on certain types of fishing activity. Until recently, the fishing regulations in force in the EFZ were those published in 1934 (Fish Industry Act), with minor changes over the years (Camilleri, 2005). These regulations included a ban on trawling within territorial waters (which at the time extended to 3 nautical miles; the restriction was maintained within 3 nautical miles even after the extension of Maltese territorial waters to 12 nautical miles in 1971). Prior to Malta's accession to the EU, a new management regime was proposed (Camilleri 2003), agreed upon and later implemented after accession through Council Regulation EC 813/2004, which, inter alia, restricted trawling to specified areas based on the trawlable grounds identified during a survey in 1978 made in collaboration with the Food and Agriculture Organization (FAO) (Giudicelli, 1978).

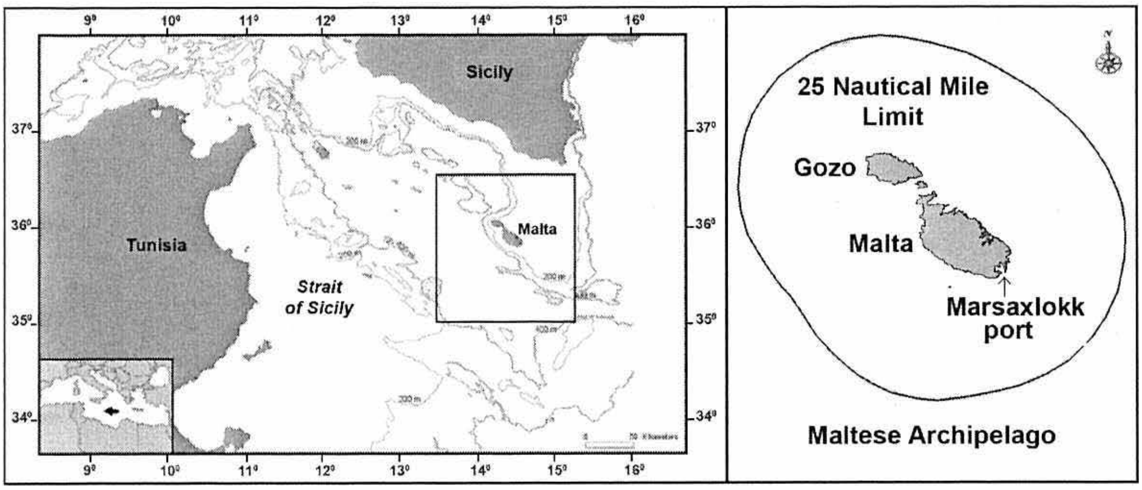

Figure 5.1 Map of the study area showing the location the Maltese Archipelago with the main island of Malta, the island of Gozo, the main fishing port of Marsaxlokk and the 25-Nautical Mile Limit.

The present study aimed to identify the main fisher groups and determine their perception towards the 'protection effect' of the FMZ including that related to the sustainability of the resources within the zone. The work tested the hypothesis that perceptions and attitudes of different fisher groups in a 35-year old exclusive fishing zone were positive. The study also tested the hypothesis that the fishers' perceptions do depend on the demographic, economic, social characteristics and fishing activity of the fishers.

5.3 Methodology

The fisheries in the Maltese archipelago constitute a relatively small industry, the social significance of which far outweighs its economic importance. Much of the fishing activity is based on traditional methods (except trawling) and operates on a small scale producing small volumes of high-value products. The industry is mainly artisanal and fairly typical of the fisheries found in many Mediterranean countries (Leiva *et al.*, 1998). Approximately 1% of the working population is dependent (to varying extents) on fishing for its livelihood. All vessels used for fishing are required by law (Malta Fishing Vessels Regulations L.425.07, 2004) to be licensed and registered in the Fishing Vessels Register (FVR). The FVR is divided into three main categories as follows: MFA (full-time commercial fishing vessels), MFB (part-time commercial fishing vessels) and MFC (non-commercial (recreational) fishing vessels). The term "full-time" is applied to fishers whose main income is derived entirely from fishing. It should be noted that fishing in Malta is mainly seasonal and consequently some of the full-time fishers own at least one small and one large vessel, which enables them to practice off-shore fishing during the calmer seasons (April – September) and coastal or inshore activities during the winter months. Approximately 20% of the fishing vessels in the Maltese archipelago are based in the fishing village of Marsaxlokk, while 14.9% are based on the island of Gozo and the rest are based in many different ports around the islands.

5.3.1 Sampling design

The attitudes and perceptions of full-time (MFA), part-time (MFB) and recreational (MFC) fishers were investigated using a questionnaire survey. Fishers to be sampled were selected according to information recorded in MALTASTAT, a reliable and efficient computerized fisheries statistics system, which includes a register/inventory of fishing vessels. The Maltese fishing fleet consists of 2252 vessels, of which there are 178 vessels of >10 m L.O.A. (8% of the fleet). Sampling was stratified by vessel length. It was planned to survey all skippers (masters) of vessels in > 10 m and the skippers of a random sample comprising 10% of the vessels < 10 m. This yielded a total sample size of 400, constituting 17.8% of the fleet. Although it is possible, in principle, for vessels from other EU member states to fish in the FMZ, in practice no foreign vessels have a licence to fish in this area.

A questionnaire was designed to evaluate the demographic characteristics, economic circumstances (costs and revenue) and activity of fishers, together with their perceptions of the Maltese 25-nautical mile FMZ. The selected skippers were surveyed by means of telephone interview in January/February 2006. In the previous September, a letter was sent to the Maltese Fisheries Board and to the fisheries cooperatives to inform them that members of their organization may be asked to participate in a fisheries survey. A letter was also sent to each of the selected registered fishers, giving them details about the survey and why it was being conducted, and that they were selected as interviewees. They were asked for full cooperation and in turn it was stated that the survey would be kept as simple as possible, so as not to take up too much of their time. Technical data on the fleet, such as vessel length, weight and power, and demographic data on vessel owners were obtained from the Malta fleet vessel register. A total of 241 interviews were conducted, equating to an overall response rate of 60.3% (Table 5.1).

Table 5.1 Sampling fractions and response rates for the questionnaire survey of different categories of fishing licence holder in Malta (MFA: full-time professional; MFB: part-time professional; MFC: recreational)

Licence category	Total no. vessels	Target sample (% of fleet)	Vessels sampled (% of fleet)	Response rate (%)
MFA	432	161 (37.3%)	122 (28.2%)	75.8
MFB	993	137 (13.8%)	72 (7.3%)	52.6
MFC	826	102 (12.3%)	47 (5.7%)	46.1
Total	2251	400 (17.8%)	241 (10.7%)	60.3

For questions regarding those factors that influence the choice of fishing site, a rank system was used in which a choice of 10 predetermined factors which could influence the choice of fishing site, were listed with an additional free-text response. The interviewees were asked to rank the five most important factors influencing their choice of fishing site in descending ranked order (i.e. with rank 1 being the most important).

Questions about perceptions of the FMZ and fishing strategies were based on a five-point Likert scale (with anchor points ranging from 'strongly agree' to 'strongly disagree'), while questions on the relationships with other users of the FMZ were based on a three-point Likert scale (with anchor points that varied between cooperation, no contact and conflict). Interview transcripts were entered into a Microsoft Access database.

5.3.2 Data analysis

For analysis, the fleet was categorised in two main ways. The first was based on the type of licence category (i.e. MFA, MFB, MFC), which reflects the livelihood dependence on fishing, with MFA licence holders deriving their entire income from fishing, MFB licence holders use fishing to supplement income from their main job, while MFC licence holders do not depend economically on fishing at all, since for them fishing is only a leisure activity.

The second classification was based on the predominant fishing gear utilised by each fisher as determined by the percentage of trips in which a particular gear was used (determined from the species landed). This is especially important in countries in which fishers use more than one type of gear. Vessels that used only one type of gear were categorised as an exclusive fishing vessel (e.g. 'exclusive trawler'), while vessels that used a particular gear 50% or more of the time spent fishing were categorised as a non-exclusive vessel (e.g. 'non-exclusive netter').

Apart from the two main categories, differences in attitudes and perceptions were also explored for other a priori designated categories. The other classifications used included home port sub-divided into three categories (the second largest island of the archipelago, Gozo, the main fishing village Marsaxlokk, and the other small fishing villages grouped together); years of fishing experience (>35 y, 15–35 y and <15 y); vessel size (>24 m, 12–24 m and <12 m l.o.a).

The fishers' responses based on the 5- and 3-point Likert scales were converted to numerical scores from 5 (fully agree) to 1 (completely disagree) and 3 (cooperation) to 1 (conflict) for the fishers' perceptions and relations respectively.

Differences among licence and gear categories in the demographic and economic characteristics of the fleet were tested with one-way analysis of variance (ANOVA) followed by the Tukey pairwise multiple comparison test. When the assumptions of ANOVA were not met, the Kruskal-Wallis test was applied, followed by the modified Dunnet pairwise multiple comparison test. When variables for only two groups were available the Mann-Withney test was used. A Bonferroni adjustment for the number of tests made within each classification was applied to counter the effects of multiple testing (Type I errors).

To test for significant positive or negative deviations from the neutral score, the numerical scores were tested using the non-parametric Wilcoxon signed rank test for each question for each category analysed.

For each respondent there were 32 dependent variables (16 Likert-scale scores and 16 coded scores) that provided a semi-quantitative representation of each individual's views on the issues discussed during the interview. These nonparametric multivariate data were analysed using PRIMER (Clarke & Warwick 2001a) to investigate how the whole suite of attitudes expressed varied within and among the five categories of fishers. A similarity matrix was constructed using the Bray-Curtis index of similarity. A one-way analysis of similarity randomized permutation test (ANOSIM) was used to investigate whether significant differences existed among the different categories of fishers identified a priori. The similarity percentages routine (SIMPER) was used to identify the attitudes that contributed most to any differences that occurred between the fishers' categories and ordination plots were created (using non-metric multi-dimensional scaling) to allow visual comparison of respondents' responses. We examined whether demographic variables pertaining to individual fishers could explain patterns in the attitudinal data using the BIOENV routine. This procedure calculated the rank correlation between similarity matrices constructed for the variables and the attitudinal data.

5.4 Results

5.4.1 General characteristics of fisher categories

The main fishing sectors identified used different types of gear throughout the year, except for bottom otter trawlers, that used this gear exclusively. The largest category of fishers were the non-exclusive seiners that use fish aggregating devices to attract, dolphin fish (*Coryphaena hippurus*). This type of fishing is carried out from 15th August until the end of December. At other times of year, these fishers practice either coastal fishing or surface longlining during the tuna season. The non-exclusive netters use trammel nets, gill nets and combined trammel-gill nets throughout the year, but also fish for dolphin fish during the peak of the dolphin fish season. The other category identified was the non-exclusive longliners, which practice longlining throughout the year. During the blufin tuna (*Thunnus thynnus*) and swordfish (*Xiphias gladius*) season they use drifting surface longlines and for the rest of the year they fish with bottom longlines. The fishers of this group also fish for dolphin fish during the peak of the season.

The remaining group identified was recreational fishers, who mostly use rod and line, hand line, and trolling lines to fish for a variety of demersal and pelagic species, mostly in coastal waters within 3 nautical miles of the coastline. The recreational fishers are also grouped by type of fishing licence (MFC).

As expected, recreational fishers differed significantly ($P<0.05$) from professional fishers (especially full-time professionals) in most respects, being older, less experienced, having smaller, less powerful, vessels, fewer 'crew', making only day trips and therefore fishing closer to port (and entirely within the FMZ), incurring lower costs and landing much smaller quantities of catch (Tables 5.2 & 5.3). The number of fishing trips per year made by recreational fishers did not differ significantly from part-time professionals, but was significantly less than full-time fishers.

With respect to the classification by licence category for the professional fishers (MFA & MFB) the type of fishery and hence the gear used did not depend on the type of licence. Nevertheless, some differences between these two groups were still detected (Tables 5.2 & 5.3). Part-time fishers use smaller, less powerful, less valuable vessels with fewer crew than full-time fishers. Although part-time fishers do not make significantly fewer trips per year, their trips are considerably shorter in duration and distance, cost less in running costs and produce landings of around 10% that of full-time fishermen by weight and value. Part-time fishers (MFB) fish mostly inside the FMZ, whereas around half of the trips undertaken by full-time fishers are outside the FMZ.

5.4.2 Choice of fishing site

All groups gave 'regulations' as the first or second most important factor influencing their choice of fishing sites, except for recreational fishers (MFC), who indicated that their choice was more closely related to accessibility to the fishing site, abundance of fish and weather (Table 5.4). The next two important decision criteria for professional fishermen were abundance of fish and weather so this may mean that fishers will change their fishing activity and fishing grounds according to the state of the resource. If a resource is depleted they will move on to the site were fish are the most abundant.

Table 5.2 Mean characteristics of fishers by license type and gear category (± standard error). Significant differences were tested for using one-way ANOVA if assumptions were met by the data, otherwise the Kruskal-Wallis test was used. Bold P values indicates significant differences; means sharing the same superscript letter are those indicated by the pairwise multicomparison tests as significantly different. MFA: full-time; MFB: part-time; MFC: recreational; BT: Exclusive Bottom Trawler; NT: Non-exclusive Netter; SN: Non-exclusive Seiner; LL: Non-exclusive Longliner.

	Licence type						
Characteristic	**MFA**	**MFB**	**MFC**	**All**	Test statistic		P
Age (y)	45^{a} (13)	48 (12)	51^{a} (13)	47 (13)	F	3.5	0.03
Time fishing (y)	24^{a} (14)	21^{b} (14)	13^{a,b} (12)	21 (14)	F	11.8	**<0.01**
Vessel length (m)	14.2 (5.9)^{a}	7.0 (2.7)^{a}	5.5 (1.7)^{a}	10.4 (6)	χ^2	126.0	**<0.01**
Gross tonnage	29.5 (46.1)^{a}	3.7 (6.2)^{a}	1.5 (1.7)^{a}	16.1 (35.3)	χ^2	123.6	**<0.01**
Engine power (kW)	182.2 (144.5)^{a}	58.7 (56.4)^{a}	33.5 (41.8)^{a}	115.7 (127.6)	χ^2	99.8	**<0.01**
Year of construction	1976 (35)	1984 (18)	1985 (19)	1980 (28)	F	2.9	0.06
Usual crew size	4 (2)^{ab}	3 (1)^{a}	2 (1)^{b}	3 (2)	χ^2	72.6	**<0.01**
Distance to fishing grounds (km)	74.5 (50.6)^{a}	23.0 (28.9)^{a}	9.7 (17.3)^{a}	41.9 (47.3)	χ^2	89.3	**<0.01**
Annual number of trips at sea	64 (61)^{ab}	36 (42)^{a}	32 (42)^{b}	45 (52)	χ^2	14.3	**<0.01**
% of trips within the FMZ	51 (41)^{a}	82 (30)a	100 (0)a	81 (33)	χ^2	42.8	**<0.01**
Trip duration (d)	5.0 (4.5)^{a}	1.6 (1.1)^{a}	1.0 (0)^{a}	3.0 (3.6)	χ^2	102.3	**<0.01**
Second-hand value of vessel and gears (Euro)	149400 (199208)	13741 (10770)	N/A	110640 (179056)	Z	-6.6	**<0.01**
Total costs of running the vessel (Euro)	6868 (16156)^{a}	2425 (3994)^{b}	792 (1360)^{ab}	3998 (11182)	χ^2	19.2	**<0.01**
Annual total landings (kg)	5338 (7326)^{ab}	601 (1465)^{a}	13 (22)^{b}	3588 (6382)	χ^2	19.3	**<0.01**
Annual value of landings (Euro)	24120 (33199)	2181 (4482)	N/A	18854 (30475)	Z	-4.7	**<0.01**

Table 5.3 Mean characteristics of fishers by license type and gear category (± standard error). Significant differences were tested for using one-way ANOVA if assumptions were met by the data, otherwise the Kruskal-Wallis test was used. Bold P values indicates significant differences; means sharing the same superscript letter are those indicated by the pairwise multicomparison tests as significantly different. BT: Exclusive Bottom Trawler; NT: Non-exclusive Netter; SN: Non-exclusive Seiner; LL: Non-exclusive Longliner.

	Gear category							
Characteristic	**BT**	**NT**	**SN**	**LL**	**MFC**	**Test statistic**		**P**
Age	46.0 (11)	48 (14)	48 (12)	43^{a} (13)	51^{a} (13)	F	2.7	0.03
Time fishing (yrs)	20 (14)	22 (15)	24^{a} (14)	22^{b} (15)	13^{a,b} (12)	F	5.6	**<0.01**
Boat length (m)	24.6 (6)^{abcde}	6.4 (1.9)b	10.4 (4.8)^{c}	11.7 (5.3)^{d}	5.5 (1.7)e	χ^2	85.9	**<0.01**
GT	126.2 (91.1)	1.9 (1.5)	11.8 (14.4)	15.4 (18.5)	1.5 (1.7)	χ^2	97.3	**<0.01**
Power (KW)	416.3 (217.5)	48.4 (39.2)	121.3 (106.8)	124.0 (100.7)	33.5 (41.8)	χ^2	72.0	**<0.01**
Year of construction	1986 (13)	1977 (28)	1979 (37)	1978 (22)	1985 (19)	F	0.6	0.67
Usual crew size	5 (2)^{ab}	2 (1)^{ace}	4 (2)^{cd}	4 (1)^{ef}	2 (1)^{bdf}	χ^2	42.9	**<0.01**
Distance to fishing grounds (km)	77.1 (41.1)^{a}	44.7 (49.3)	54.8 (56.0)^{b}	41.9 (37.9)^{c}	9.7 (17.3)^{abc}	χ^2	50.7	**<0.01**
Annual number of trips at sea/year	68 (26)	36 (42)	47 (54)	54 (58)	32 (42)	F	1.1	0.35
% of trips at sea inside the FMZ	65.0 (49.5)	79.0 (30.0)	65.2 (40.9)^{a}	75.8 (33.8)^{b}	100 (0)^{ab}	χ^2	30.8	**<0.01**
Trip duration (days)	3.2 (1.5)	1.8 (1.3)	4.1 (3.8)	3.7 (4.5)	1.0 (0)	F	0.9	0.43
Second-hand value of boat and gears (Euro)	517678 (279724)^{abc}	9918 (49230)^{aef}	85794 (158009)^{be}	84849 (78514)^{cf}	N/A	χ^2	22.5	**<0.01**
Total costs of running the vessel (Euro)	3860 (6911)	3141 (6900)	6777 (16862)^{a}	2912 (4157)^{b}	792 (1360)^{ab}	χ^2	19.9	**<0.01**
Annual total landings (kg)	9011 (9281)	10872 (9411)	3457 (6333)^{a}	3478 (5848)^{b}	13 (22)^{ab}	χ^2	14.3	**<0.01**
Annual value of landings (Euro)	42188 (34639)	12487 (15932)	20014 (31491)	14321 (28423)	N/A	F	2.1	0.11

Table 5.4 Most important factors influencing the choice of fishing site given by different groups of fishers. MFA – Full-time; MFB - Part-time; MFC – Recreational; BT – Exclusive Bottom Trawler; NT - Non-exclusive Netter; SN – Non-exclusive Seiner; LL – Non-exclusive Longliner.

		Factor affecting choice of fishing site				
		Most Important				Least Important
Classification	Category	1	2	3	4	5
Gear category	**Exclusive bottom trawler**	Abundance of fish	Regulations	Weather	Distance to port	Experience
	Non-exclusive netter	Experience	Regulations	Abundance of fish	Weather	Distance to port
	Non-exclusive seiner	Regulations	Weather	Experience	Abundance of fish	Distance to port
	Longliner	Regulations	Weather	Experience	Abundance of fish	Equipment
Licence category	**MFA**	Regulations	Experience	Abundance of fish	Experience	Distance to port
	MFB	Experience	Regulations	Abundance of fish	Weather	Distance to port
	MFC	Accessibility	Abundance of fish	Weather	Experience	Regulations
Time fishing	**<15 y**	Regulations	Experience	Abundance of fish	Weather	Accessibility
	15-35 y	Regulations	Abundance of fish	Weather	Experience	Distance to port
	>35 y	Regulations	Weather	Experience	Abundance of fish	Season
Base port	**Other**	Regulations	Experience	Weather	Abundance of fish	Accessibility
	Marsaxlokk	Regulations	Weather	Abundance of fish	Experience	Season
	Gozo	Regulations	Abundance of fish	Experience	Distance to port	Weather
Vessel size	**<12 m**	Experience	Regulations	Weather	Abundance of fish	Accessibility
	12–24 m	Regulations	Abundance of fish	Weather	Experience	Go were other fishers go
	>24 m	Regulations	Abundance of fish	Weather	Distance to port	Go were other fishers go
Overall		Regulations	Abundance of fish	Weather	Experience	Distance to port

5.4.3 Fishers' perceptions

In general the different classifications of fishers had similar perceptions of the effectiveness of the FMZ in some aspects but there were some different perceptions that occurred among the different groups (Figure 5.2). The perceptions of trawlers and netters sometimes deviated from the neutral response (score 3) but these were not significant deviations which implied that the fishers do not think that the FMZ has an impact in relation to the questions posed to them (Table 5.5).

Most of the fishers in each of the different categories thought that the establishment of the FMZ has had an overall negative impact on their fishing activity. Significant results ($P<0.05$; Table 5.5) were obtained for seiners, longliners, fulltime, recreational, experienced and non-experienced fishers, all base ports (except Gozo) and all of the vessel length classes (except vessels > 24m). Trawlers were the only group which declared that the FMZ had no impact on their fishing activity.

When questioned about the effect of the FMZ in protecting biodiversity, most respondents responded with either a neutral response or indicated that the FMZ does not help to protect biodiversity. Significant negative results ($P <0.05$; Table 5.5) were obtained for full-time fishers, fishers from Marsaxlokk port and the 12-24 m vessels. Only recreational fishers thought that the FMZ helped to protect biodiversity ($P<0.05$; Table 5.5). Fishers with >35 year's fishing experience thought that the FMZ did not enhance fish abundance in the area ($P<0.05$; Table 5.5), while the rest of the groups analysed had an overall neutral response.

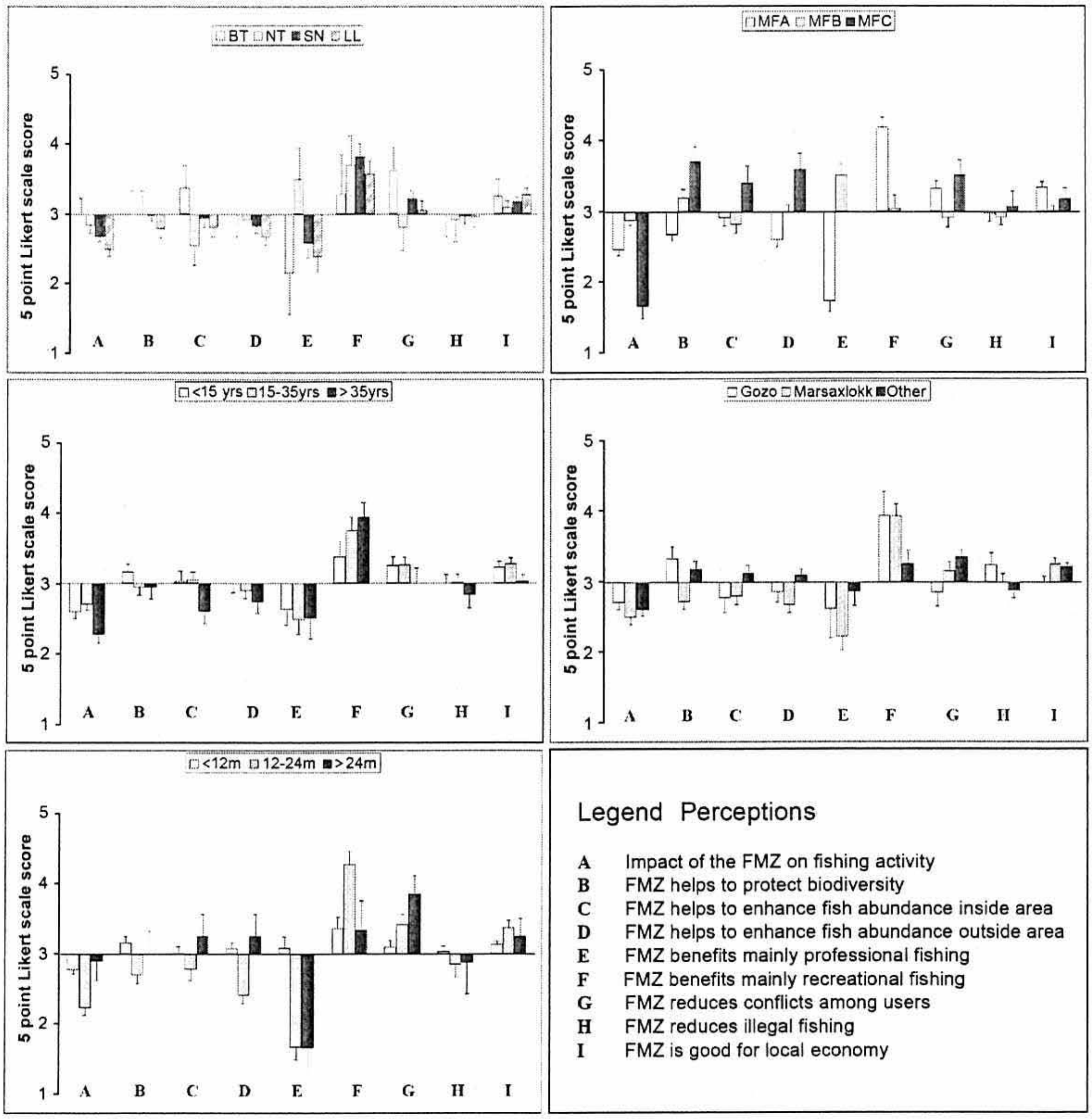

Figure 5.2 Fishers' perception of the FMZ of different fishers' groups from 1 fully disagree agree to 5 fully agree on the 5 point Likert scale. The error bars show the standard error. The legend from A – I shows the questions asked. MFA – Full-time; MFB - Part-time; MFC – Recreational; BT – Exclusive Bottom Trawler; NT - Non-exclusive Netter; SN – Non-exclusive Seiner; LL – Non-exclusive Longliner.

Table 5.5 Results of Wilcoxon ranked test for differences from a neutral response to questions about attitudes to the FMZ. Values in bold indicate significant differences at P<0.05. MFA – Full-time; MFB - Part-time; MFC – Recreational; BT – Exclusive Bottom Trawler; NT - Non-exclusive Netter; SN – Non-exclusive Seiner; LL – Non-exclusive Longliner.

Gear category	BT		NT		SN		LL	
	W statistic	P	W statistic	P	W statistic	P	W statistic	P
A	3	1.00	0	0.37	123	**<0.01**	60	**<0.01**
B	3	1.00	11	1.00	231	0.74	119	0.06
C	8	0.36	8	0.18	602	0.57	349	0.14
D	3	1.00	20	0.81	197	0.09	165	**<0.01**
E	3	0.28	32	0.31	402	0.04	426	**<0.01**
F	9.5	0.69	36	0.12	1144	**<0.01**	991	**<0.01**
G	18	0.14	10.5	0.61	468	0.08	277	0.82
H	3	1.00	16	0.83	479	0.66	415	0.65
I	7.5	0.47	1	1.00	241	**0.04**	380	**0.01**

Questions	
A	Impact of the FMZ on fishing activity
B	FMZ helps to protect biodiversity
C	FMZ helps to enhance fish abundance inside area
D	FMZ helps to enhance fish abundance outside area
E	FMZ benefits mainly professional fishing
F	FMZ benefits mainly recreational fishing
G	FMZ reduces conflicts among users
H	FMZ reduces illegal fishing
I	FMZ is good for local economy

Licence type	MFA		MFB		MFC	
A	184	**<0.01**	51	0.14	0	**<0.01**
B	55	**<0.01**	545	0.14	193	**<0.01**
C	699	0.42	502	0.19	223	0.11
D	171	**<0.01**	390	1.00	246	0.03
E	331	**<0.01**	700	**<0.01**		N.A
F	2343	**<0.01**	607	0.66		N.A
G	901	**0.01**	225	0.47	208	0.04
H	755	0.73	399	0.52	175	0.76
I	830	**<0.01**	81	0.85	46	0.29

Base port	Gozo	Marsaxlokk		Other	
6	0.02	190	**<0.01**	32	**<0.01**
53	0.09	168	**0.03**	633	0.11
57	0.37	616	0.14	995	0.28
24	0.45	364	**0.01**	654	0.35
67	0.42	417	**<0.01**	323	0.67
138	0.02	1456	**<0.01**	564	0.16
42	0.50	554	0.33	873	**<0.01**
83	0.21	676	0.73	643	0.29
5	1.00	525	**<0.01**	388	**<0.01**

Time fishing	<15yrs		15-35yrs		>35yrs	
A	17	**<0.01**	240	**<0.01**	173	**<0.01**
B	341	0.29	344	0.53	113	0.75
C	641	0.78	789	0.69	117	**0.03**
D	392	0.98	366	0.29	129	0.11
E	133	0.11	612	0.02	348	0.09
F	289	0.13	1514	**<0.01**	114	**<0.01**
G	447	0.08	784	0.04	152	1.00
H	406	0.96	800	0.99	36	0.36
I	185	**0.02**	630	**<0.01**	36	0.77

Vessel size	<12m	12-24m		>24m	
175	**<0.01**	31	**<0.01**	4	0.86
1503	0.13	27	**0.03**	3	1.00
2112	0.94	258	0.16	5	0.59
1614	0.44	35	**<0.01**	5	0.59
1130	0.71	128	**<0.01**	0	0.10
1546	0.02	1041	**<0.01**	5	0.59
1391	0.39	349	0.02	15	0.06
1808	0.77	254	0.32	7	0.89
616	0.04	296	**<0.01**	8	0.47

With respect to the fish abundance outside the area, most of the fishers did not think that the FMZ benefited stocks outside the area. Significant negative responses ($P<0.05$; Table 5.5) were obtained for longliners, full-time and recreational fishers, fishers from Marsaxlokk port and the 12-24m vessels. The response from the recreational fishers was not significant after the bonferroni correction. (Table 5.5).

Most fishers thought that the FMZ did not benefit professional fishers (MFA & MFB), with significant negative responses for longliners, full-time, fishers from Marsaxlokk port and 12-24m vessels ($P <0.05$; table 5.5). Interestingly, part-time fishers thought that the FMZ benefited professional fishers ($P <0.05$; Table 5.5). All of the recreational fishers declined to comment whether the FMZ mainly benefited professional or recreational fishers. Most of the professional fishers considered that the FMZ benefited mainly recreational fishers ($P <0.05$; Table 5.5).

Most fishers expressed the view that the FMZ reduced conflicts among users and that it is good for the local economy ($P<0.05$; Table 5.5). The fishers also stated that the FMZ had no impact on illegal fishing.

When asked about the relationship with other users, all groups answered that they had good cooperation with all users, with the exception that professional fishers considered that there was conflict with foreign fishers when fishing outside the FMZ. For ease of interpretation, results are presented graphically only for the professional (MFA & MFB) and recreational (MFC) fishers (Figure 5.3).

Fishers were asked whether the FMZ had influenced their manner of fishing and 32% of the respondents answered positively. The main reason for changes in behaviour were that they had ceased to fish in the FMZ (75%), that they now targeted other species (13%) or that they had purchased another vessel (4%).

When considering the whole suite of responses together, the multivariate analysis indicated significant differences (ANOSIM P<0.05, Table 5.6) in the fishers' perceptions by gear and licence category, years fishing and vessel length. Positive R values indicate some discrimination between the groups whereas negative values indicate that within each group differences are greater than those between groups. In relation to gear type category, the responses of recreational fishers (MFC) differed significantly from all other groups, which were not significantly different from each other (ANOSIM P< 0.05, Table 5.6). The analysis of classification by licence type exhibited the largest global R statistic (ANOSIM P<0.05, Table 5.6), with significant differences between all three groups (Fig. 5.4). The recreational fishers and full-time fishers exhibited the greatest differences, while the part-time fishers were intermediate between these two groups. The full-time fishers appeared to exhibit the greatest variability in their responses.

Fishers who have been fishing for more than 35 years had significantly different perceptions regarding the FMZ (ANOSIM P<0.05, Table 5.6) compared with less-experienced fishers, mostly in that they think that the FMZ does not enhance fish abundance in the area and it does not reduce illegal fishing (Fig 5.2).

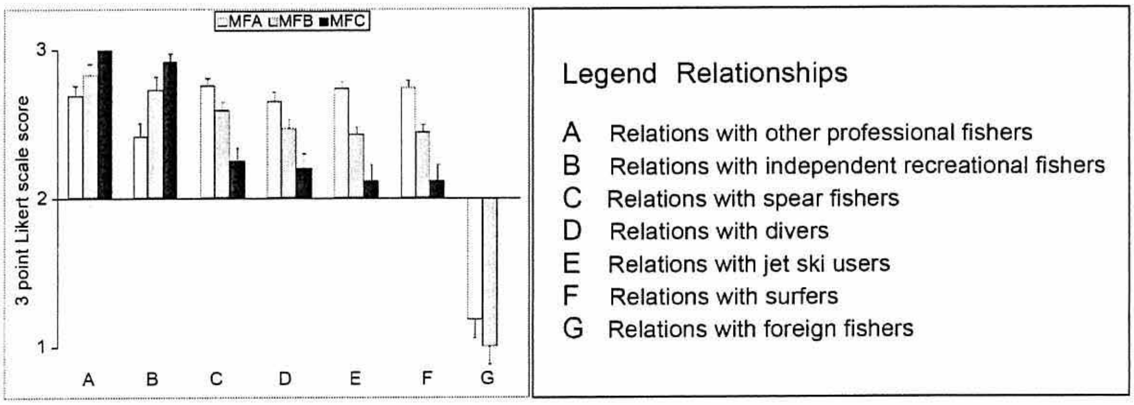

Figure 5.3 Fishers' perceptions of relationships with other users of the FMZ for the fulltime (MFA), part-time (MFB) and recreational fishers' (MFC), from 1 conflict to 3 good cooperation on the 3 point Likert scale. The error bars show the standard error. The legend from A – G shows the questions asked.

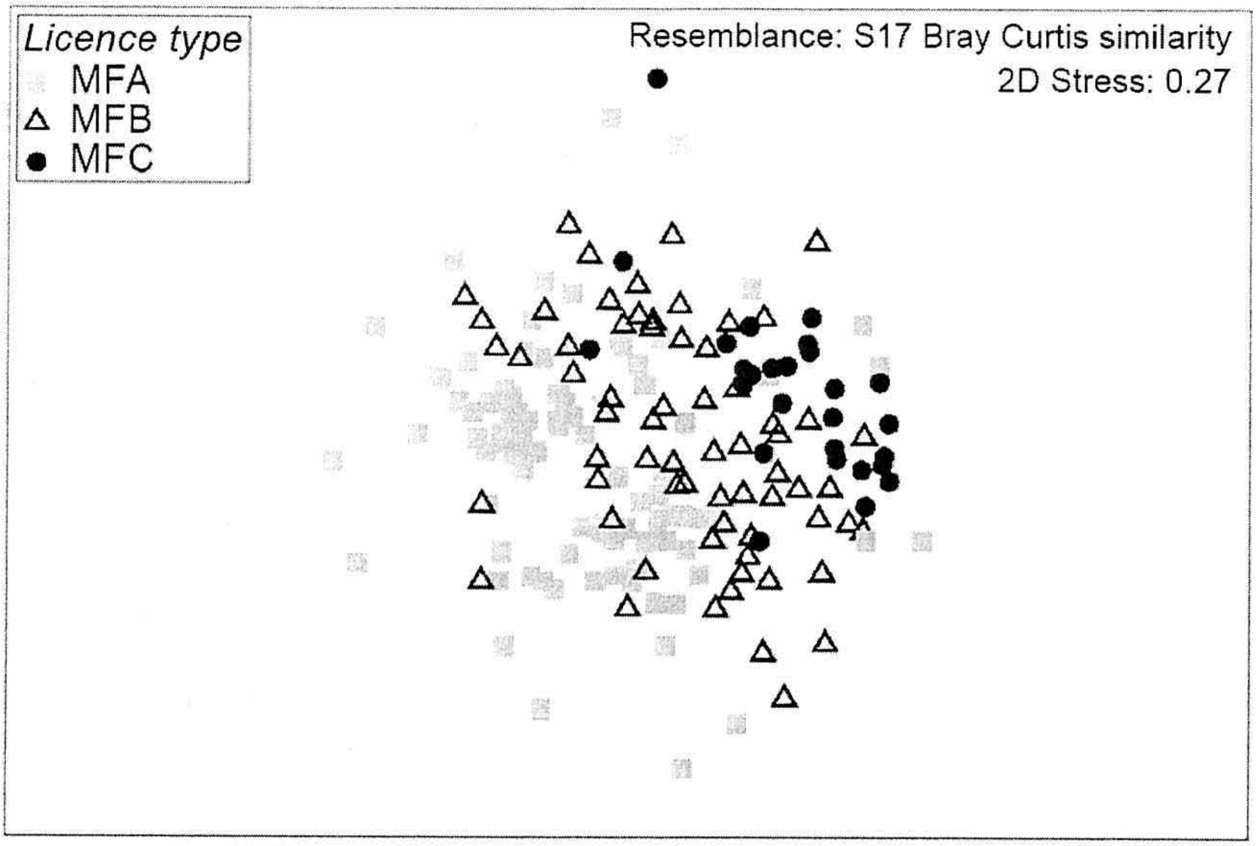

Figure 5.4 Non-metric multidimensional scaling (nMDS) plot for the replicate questionnaires based on the 32 dependent variables showing the labels by licence category MFA – Full-time fishers, MFB – Part-time Fishers and MFC – Recreational Fishers.

The opinions of fishers from the main fishing village of Marsaxlokk were significantly different (ANOSIM P <0.05, Table 5.6) from all other fishing villages in that practically the protection and enhancing effect of the FMZ on the stocks is not happening (questions B, C, D) and it does not reduce illegal fishing (Fig 5.2). The opinions of fishers also differed significantly in relation to size of vessel (ANOSIM P<0.05, Table 5.6) where larger vessel (>24m) skippers perceived that the FMZ does not enhance fish abundance.

Table 5.6 Multivariate analysis of similarity (ANOSIM) test results for the 32 dependent variables and the respective groupings. The test statistic R is given for each pairwise comparison, with its associated probability. The bold figures show significant differences. MFA – Full-time; MFB - Part-time; MFC – Recreational; BT – Exclusive Bottom Trawler; NT - Non-exclusive Netter; SN – Non-exclusive Seiner; LL – Non-exclusive Longliner.

Groups	R Statistic	P	Groups	R Statistic	P
Gear category	0.09	**0.002**	**Base port**	0.004	0.375
SN, LL	0.004	0.34	Marsaxlokk, Gozo	0.033	**0.007**
SN, BT	-0.059	0.703	Marsaxlokk, Other	-0.145	0.999
SN, NT	-0.057	0.772	Gozo, Other	0.034	0.236
SN, MFC	0.183	**0.001**			
LL, BT	0.002	0.465	**Years fishing**	0.032	0.028
BT, NT	0.028	0.333	>35 y, 15-35 y	0.07	0.029
LL, MFC	0.329	**0.001**	>35 y, <15 y	0.105	**0.002**
BT,NT	-0.02	0.572	15-35 y, <15 y	-0.015	0.877
BT, MFC	0.456	**0.001**			
NT, MFC	0.465	**0.001**			
Licence type	0.131	**0.001**	**Vessel length**	0.119	**0.001**
MFA, MFB	0.074	**0.001**	12-24m, >24m	0.157	**0.001**
MFA, MFC	0.188	**0.001**	12-24m, <12m	0.127	**0.001**
MFB, MFC	0.229	**0.001**	>24m, <12m	0.036	**0.001**

Key statements that contributed most to the similarity of attitudes expressed within groups of each classification and those that accounted most for the between-group dissimilarities for each classification were identified by the SIMPER routine (Table 5.7). The differences in the choice of fishing site were the most important factors contributing to the dissimilarity followed by responses on the benefit and protection effect of the FMZ to fisheries.

The BIOENV analysis revealed that a combination of three demographic variables gave the best rank correlation with the responses made by fishers. The most positive correlations were obtained by the combined variables license category and owner of vessel (0.173); however the correlation coefficients were all very low.

Table 5.7 The top ten results of the SIMPER Analysis showing key statements that contributed most for the between-group dissimilarities for the licence category. MFA – Full-time; MFB - Part-time; MFC – Recreational.

MFA & MFB

Average dissimilarity = 24.12

Attitude/perception	MFA Mean response	MFB Mean response	Av. Diss	SD	Diss/ SD	Contrib. %	Cum %
Factor affecting choice of fishing site - Regulations	2.52	2.24	2.28	2.0	1.13	9.45	9.45
Factor affecting choice of fishing site - Experience	0.65	2.49	2.19	1.9	1.15	9.09	18.55
Factor affecting choice of fishing site - Weather	1.98	1.03	1.89	1.8	1.05	7.84	26.39
FMZ benefits mainly professional fishing	1.91	3.49	1.81	1.2	1.51	7.52	33.91
Factor affecting choice of fishing site - Abundance of fish	1.37	1.25	1.69	1.8	0.92	7.00	40.91
FMZ benefits mainly recreational fishing	4.00	3.06	1.51	1.2	1.30	6.26	47.17
FMZ helps to enhance fish abundance inside area	3.00	2.82	1.02	0.8	1.25	4.22	51.39
FMZ reduces illegal fishing	3.03	2.93	0.99	0.8	1.18	4.09	55.47
Influence of MPA on the way to fish	1.96	1.24	0.88	0.9	1.01	3.67	59.14
FMZ helps to protect biodiversity	2.76	3.19	0.87	0.8	1.10	3.61	62.75

MFA & MFC

Average dissimilarity = 26.52

Attitude/perception	MFA Mean response	MFC Mean response	Av.D iss	SD	Diss/ SD	Contrib. %	Cum. %
Factor affecting choice of fishing site - Regulations	2.52	1.00	2.31	2.0	1.14	8.72	8.72
Factor affecting choice of fishing site - Abundance of fish	1.37	2.15	2.10	2.0	1.05	7.91	16.63
Factor affecting choice of fishing site - Weather	1.98	1.74	2.00	1.7	1.16	7.55	24.18
Factor affecting choice of fishing site - Accessibility	0.06	2.22	1.94	1.9	1.00	7.32	31.5
Factor affecting choice of fishing site - Experience	0.65	1.37	1.40	1.5	0.92	5.30	36.8
FMZ benefits mainly professional fishing	1.91	3.00	1.36	0.9	1.73	5.13	41.93
FMZ helps to enhance fish abundance outside area	2.67	3.59	1.31	0.8	1.51	4.96	46.89
FMZ benefits mainly recreational fishing	4.00	3.00	1.23	0.8	1.56	4.64	51.53
FMZ helps to protect biodiversity	2.76	3.70	1.21	0.9	1.37	4.55	56.08
FMZ helps to enhance fish abundance inside area	3.00	3.41	1.20	0.9	1.34	4.51	60.59

MFB & MFC

Average dissimilarity = 23.77

Attitude/perception	MFB Mean response	MFC Mean response	Av.D iss	SD	Diss/ SD	Contrib. %	Cum. %
Factor affecting choice of fishing site - Experience	2.49	1.37	2.20	1.8	1.21	9.25	9.25
Factor affecting choice of fishing site - Regulations	2.24	1.00	2.13	1.9	1.10	8.94	18.19
Factor affecting choice of fishing site - Abundance of fish	1.25	2.15	2.04	1.9	1.06	8.56	26.75
Factor affecting choice of fishing site - Accessibility	0.00	2.22	1.94	2.0	0.98	8.18	34.93
Factor affecting choice of fishing site - Weather	1.03	1.74	1.70	1.6	1.06	7.17	42.09
FMZ helps to enhance fish abundance inside area	2.82	3.41	1.25	1.0	1.29	5.25	47.34
FMZ helps to enhance fish abundance outside area	3.00	3.59	1.16	0.9	1.36	4.88	52.22
FMZ helps to protect biodiversity	3.19	3.70	1.13	0.9	1.25	4.77	56.99
FMZ reduces illegal fishing	2.93	3.07	1.08	0.8	1.28	4.56	61.55
FMZ reduces conflicts among users	2.93	3.52	1.08	0.8	1.35	4.56	66.1

5.5 Discussion

The aim of the study was to determine the perceptions and attitudes of the resource users that have exclusive access to the FMZ that was established primarily to conserve fish stocks for Maltese fishers. Following accession to the EU in 2004 the aim of the zone was to act as a fisheries conservation area in the Sicilian Channel. Fishers' perceptions and attitudes may also change with time as new generations replace the old ones and the former become accustomed to their present situation and hence the original perception of the exclusivity of the zone may be lost. This was examined by looking at the perceptions and attitudes of fishers that fished prior to the establishment of the original 25 nautical mile exclusive fisheries zone in 1971.

The characteristics of the fishers differed mostly between the professional and recreational fishers and to a lesser extent between the commercial full-time and part-time fishers. Full-time professional fishers expressed stronger opinions than part-timers, who were neutral on most issues. Recreational fishers were moderately opinionated too, but with different views. For the gear categories investigated, no major differences were evident, except for netters who have smaller boats and hence a low second hand value of the boat. Total costs and landings are similar throughout the professional gear classes except for bottom trawlers which had the highest annual values for landings (ca. €42,000 annually as opposed to ca. €15,000 annually for the other categories). The other commercial fleet categories had similar total value of landings (ca. €15,000 annually) with the netters having almost three times as much landings (ca. 10 t as opposed to 3 t) than the seiners and longliners, however none of these differences were significant due to the high variability in the data. One reason for the lack in differences between the longliners and seiners is that some fished species yield high unit values in a short period of time, such as in the longline bluefin tuna fishery and other fished species yield relatively low unit value spread over a longer period of time, as illustrated by the dolphinfish fishery undertaken by seiners. Bottom trawlers on the other hand exert comparatively constant fishing effort, targeting deep water red shrimp (Aristeomorpha foliacea) throughout the year yielding the highest landings in terms of value.

The most important factor that determines the choice of fishing site was fishery regulations. The reason that many of the fishers responded that regulations are the most important may be due to the fishers being afraid that the questionnaire would be used for enforcement proposes. This may also mean that some responses could have been answered inappropriately on purpose if there was any irregularity to their fishing activity and can have lead to the unwillingness of certain fishers to answer some of the questions. Nevertheless regulations seem important for fishers and this means that regulations and their enforcement are vital for the success of fisheries management.

5.5.1 Fishers' perceptions and attitudes

In general, the perceptions of the fishers were that the FMZ has had a negative impact on fishing activity. Professional fishers may perceive that the FMZ does not protect fishery resources, since their major income comes from highly migratory species that include dolphin fish, bluefin tuna and swordfish, which comprise more than 80% of the total annual landings (Agriculture and Fisheries statistics 2005). Highly migratory species are not protected by marine protected areas or fisheries restricted areas such as the FMZ, since these resources have open access to a multitude of fishers outside the conservation zone. The negative perceptions of these fishers about the conservation effect of the FMZ and its use in the conservation of the stocks were also perceived by the interviewers while administering the interviews. The fishers' lack of ownership of the migratory resources was raised by many with comments such as 'fish are caught by big foreign boats' and 'foreign boats are ruining our gear', and this is reflected in the responses to questions about 'conflict' for which conflicts were indicated only with foreign fishers (Fig. 5.3). Another reason for the negative perceptions of the fishers on the FMZ is that following the accession of Malta into the EU in 2004 a restriction was applied that vessels > 12 m could not fish within the 25-NM zone except for trawling, dolphinfish fishery, purse seining for small pelagics (lampara), and fishing for tuna, swordfish and other highly migratory species. This meant that netters and bottom longliners > 12 m were excluded from fishing in the FMZ.

In contrast to pelagic fishers, trawlers and netters that fish for demersal species had an overall neutral response and may either perceive slightly the benefits of the conservation area or have been accustomed to any benefits the FMZ might have since these fishers have been fishing in the FMZ for a large number of years. Bottom trawlers and netters also seem to have the most incentive towards property rights, since the stocks they target are not migratory and therefore remain within the FMZ.

Older fishers claim that the FMZ did not help in enhancing fish abundance inside the conservation area. This may be due to the fact that the old fishers were accustomed to fishing in inshore and coastal waters and had to move further away from the coast for fishing as fish stocks declined over time. Since the establishment of the exclusive fishing zone in 1971, the population of the Maltese archipelago has increased from 326,000 in 1970 to 403,500 in 2005. The number of commercial and recreational fishers increased correspondingly. In the 1970s through to the 1990s there was also an increase in the number of spear fishers, which drastically reduced the number of coastal large demersal fish, such as groupers (*Epinephelus* spp.) and bream (Sparidae spp.). According to the fishers that have been fishing for more than 35 years, accounts of 'large fish being caught very close to the coast are a thing of the past'. The shift from the fishing in inshore to offshore waters can be clearly seen from the national total landings in figure 5.5. The total landings for demersal species decreased drastically in 1991 and landings for large pelagics mostly due to Blufin tuna (*Thunnus thynnus*) increased drastically in 1993-94. The landings for demersal species started to increase again in 1996 since bottom longliners started fishing offshore as well. Fig 5.6 shows the trend in the landings per unit effort for the Maltese islands and it is clear from the graph that the landings per vessel have decreased by half since 1963. These graphs confirm the overall negative fishers' perception of the FMZ which does not seem to have functioned properly as a conservation zone. The decreasing trend in LPUE is due to the continued increase in the number of vessels since 1954 and the increased fishing capacity of the vessels with the introduction of engine power and better equipment for fishing.

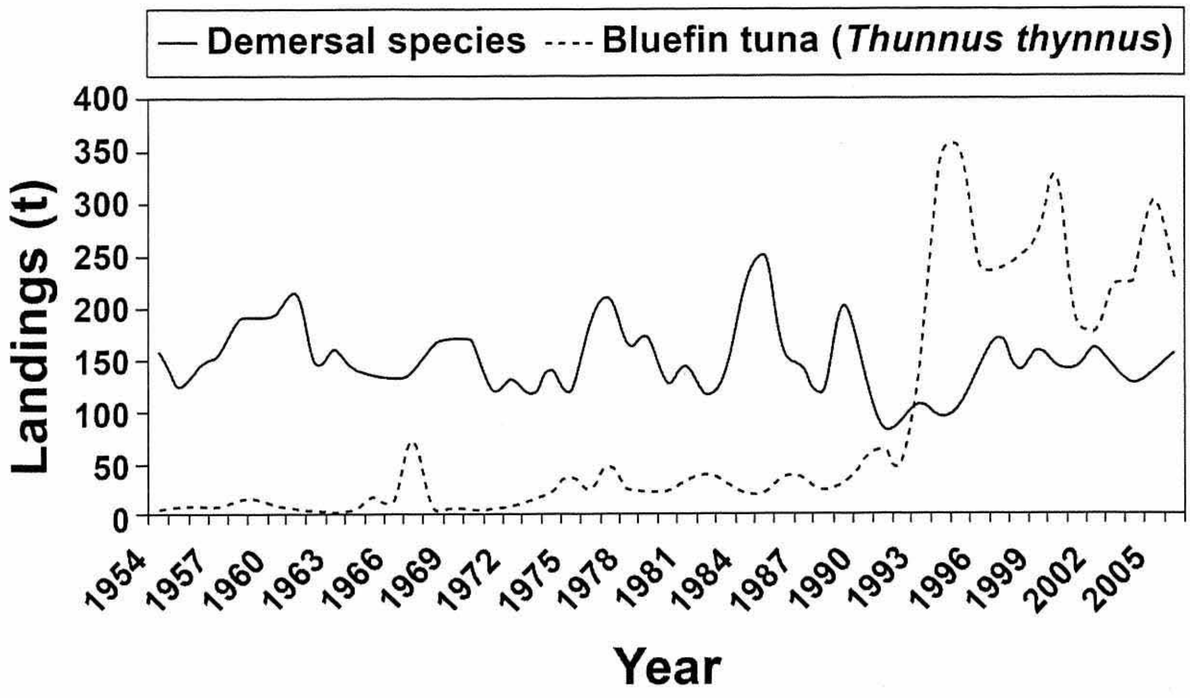

Figure 5.5 Total landings (t) from the Maltese Islands for bluefin tuna and demersal species from 1954 to 2006.

Most fishers expressed the view that the FMZ reduced conflicts among users and that it is good for the local economy, however the fishers also clearly stated that conflicts arose with foreign fishers, so probably their response was directed towards reducing conflicts between local fishers. Furthermore the fishers responded that the FMZ is good for local economy but most groups investigated claimed it had a general negative impact on the fish abundance inside and outside the zone. These two statements are in contradiction. One possible reason for this is that the fishers response to the FMZ as being important for local economy may be directed towards the economy of the country but not for the fishers' economy ($P<0.05$; Table 5.5). The fishers also stated that the FMZ had no impact on illegal fishing so the control and enforcement system in place either is not having effect on illegal fishing or is not being perceived by the fishers.

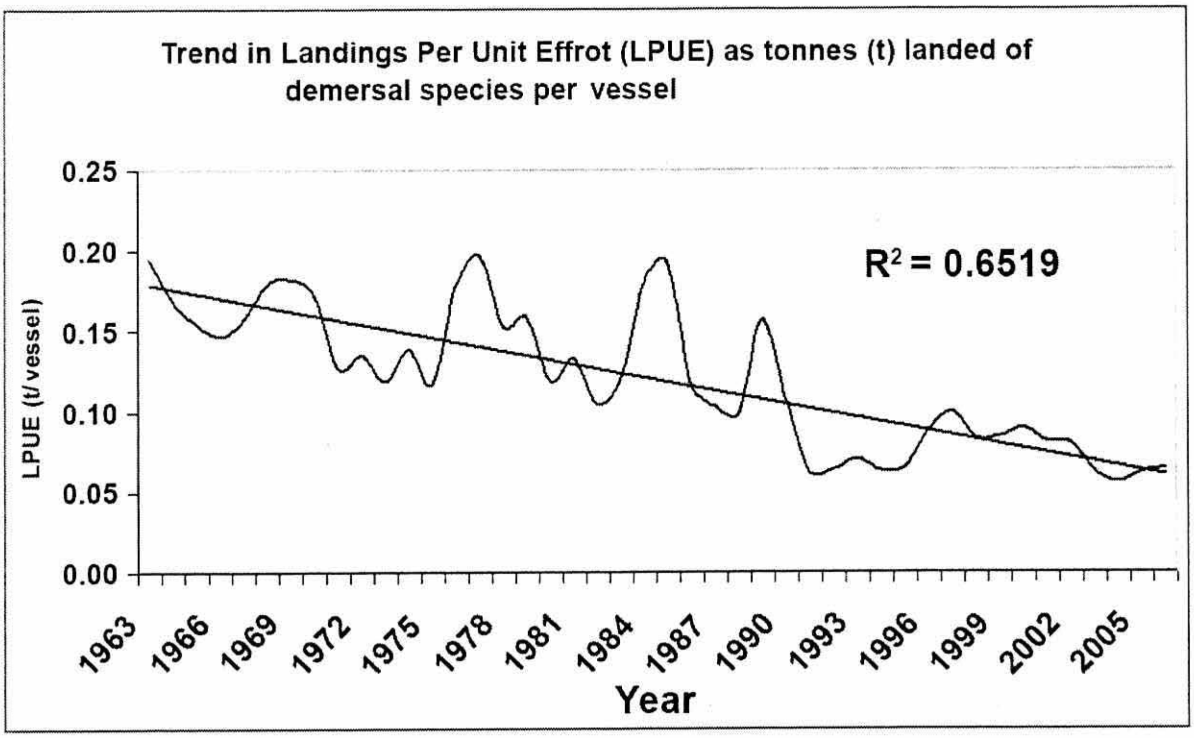

Figure 5.6 Trend in Landings Per Unit Effort (LPUE) for the Maltese Islands for the demersal species from 1963 to 2006.

Although all the groupings investigated show some differences in perceptions, the largest differences were those between the recreational and the professional fishers, with the former having strong beliefs that the FMZ was set up to protect marine resources inside the zone. When the whole suite of attitudes was analysed, the main differences were between the three licence categories (MFA, MFB, MFC) and fishers that have been fishing for more than 35 years and the ones which have been fishing less. Apparent differences in relation to vessel length may have been confounded with licence category.

The most evident differences were between the three licence categories, where the multivariate analysis indicated that the full-time fishers are at one extreme and recreational fishers at the other, although there was an attitudinal continuum between the three groups of fishers. According to Gelcich *et al.* (2005a), understanding the complexity in livelihoods of artisanal fishers is crucial to understanding the driving forces behind fishers' behaviours. The results of the present study show that the dependence on fishing for the fisher's income was the strongest factor influencing attitudinal differences. The importance of managing fishers according to their livelihood has been recognised also by other studies (Scoones 1998; Allison & Ellis 2001), since it may improve rural development policy and practice by recognizing the seasonal complexity of livelihood strategies. In this approach, it is necessary to consider the conditions that create economic niches for coastal residents and that relate to specific lifestyles (Allison & Ellis 2001). The livelihoods approach to fisheries also fits with the ecosystem approach to fisheries management (Jorgensen & Muller 2000) and extends it to take local socioeconomic factors into account. In this particular case study the management system based on the livelihood approach is already in place with the current vessel licensing system

Social influences on the fishers' behaviour were reflected in the different overall attitudes of fishers from the main fishing of Marsaxlokk. Fishers from this village are known locally to be particularly different in their attitudes from other localities. In fact, the people from this village also have their own dialect and accent. The social background of fishers from this village may have influenced their perceptions. The village has the longest history of fishing activity, with stories of fishing in past times being passed down the generations, so the particular cultural and social characteristics of this village may have accounted for the attitudinal difference of its fishers.

5.5.2 Management implications

Significant differences in resource use, world views, and attitudes exist among artisanal fishers in Malta, as in many other countries (Sandersen & Koester 2000; Perez- Sánchez & Muir 2003; Hampshire *et al.* 2004). These differences must be identified and understood if co-management and conservation are to be more inclusive and participatory and thus more effective (Sandersen & Koester 2000; Sittert 2003). Current management assumes that fishers will respond homogeneously and deterministically to a given management action. Our results, however, suggest that the attitudes of fishers to management tools depend on their dependence on fishing for their livelihoods, origin and experience fishing. Hence, the management response is likely to be variable both among groups and among individuals within any group. Understanding this variability is important in predicting the likely success of any given management measure.

Although at one level, individual differences in circumstance may make different people respond differently to the same management tool, it is clearly unrealistic for policy makers to consider all individual responses separately. So to aid understanding of these differences, some sort of loose taxonomy of "response type," as determined by attitudes, objectives, and other socioeconomic variables, may be helpful. Based on our current understanding of the Maltese situation, it seems that different fisher groups have different attitudes towards the FMZ. For the situation we studied, fishers can be grouped into one of three domains of attitudes: recreational, commercial full-time and commercial part-time.

The main causes of attitudinal heterogeneity among fishers of different groups are related to their attitude toward the protection and conservation effect of the FMZ, enhancement of resources and conflicts. The differences in fishers' attitudes between the commercial and recreational fishers toward these key issues are especially important, because human behaviour is determined by specific attitudes and the beliefs that people hold (Ajzen 1988; Beedell & Rehman 1999). Consequently, these underlying attitudes could lead to future observable differences in management style. These attitudes influence fishers' voluntary participation in enforcing regulations (for example, by reporting illegal fishing activities) and thus affect the wider impact on marine natural resources. At the moment this is already happening in the FMZ since local fishermen routinely report foreign fishers, especially trawlers that enter in the zone to fish illegally. This attitude had been detected in the relationships analysis where the fishers have recorded strongly their conflict with the foreign fishers (Fig 5.3).

The suite of attitudes and perceptions studies gave slight positive correlations with the licence category (MFA, MFB, MFC) being the most important. Nevertheless no combination of demographic variables correlated significantly with the subset of questions, which indicated that this attitudinal domain was determined primarily by other factors, such as social norms (Aipanjiguly *et al.* 2003), ethical considerations, and personality, as has been found for farmers (Willock *et al.* 1999).

The importance of individual attitudes in determining behaviour raises the possibility that although a new management action or tool may change fishers' short-term behaviour, if the management policy is not accompanied by any changes in fishers' perception and social norms, after a period of time that the management tool is implemented or in times of crisis, fishers may revert to their traditional behavioural patterns, which could compromise long-term fisheries sustainability (Pretty 2003). Hence fishers' participation is vital in the management implementation process. Furthermore, once a management policy is adopted and the appropriate management actions are taken, regular monitoring of the fishers perceptions must be implemented to determine if the new management decisions had the desired effect on the attitude of the fisher. The results obtained from monitoring activities will be useful for an adaptive management, and should contribute to the process of continued improvement of the effectiveness of the proposed system (Jacobson *et al.*, 2003).

Communication is very important for the successful implementation of new policies and management actions, in that it can influence the attitude of stakeholders to new iniatives. All the stakeholders that are present within the FMZ are in fact the recipients of the messages concerning the area itself or the activities carried out in it. The aims of the communication activities answer, above all, to the stakeholders' need on FMZ knowledge and in particular that related to its fisheries sustainability, conservation and environmental characteristics and its knowledge with regards to the Maltese context. Fishers are more likely to comply with management measures and persuade others to do so if they have been consulted, been convinced of their need and had the opportunity to contribute to their formulation. Poor communication, on the other hand, is likely to lead to resentment of authority and resistance to new regulations.

However the issue arises if long-standing attitudes can be changed given the present age-related differences in attitudes, will the "attitude-profile" of the fisher population change over time, or are these attitudes determined by age and experience independently from the historical context? Can perception of management measures be altered favourably? Can management measures be designed for particular fisher groups to have the desired effect depending on the attitudes of the group? These are all questions that must be addressed and need further research if the future of fisheries management aims to be fully successful.

Chapter 6

General discussion

6.1 Relationships between demersal assemblages, infauna and sediment characteristics (Chapters 2 and 3)

In the first two chapters an attempt was made to find habitat characteristics (biotic and abiotic) that would be directly or indirectly related to the demersal assemblages in Maltese trawlable grounds. The first study was done on a local scale inside the FMZ while the second attempted was done at a wider geographical scale. The habitat characteristic investigated included prey items for the demersal fish fauna, that were investigated by looking at discarded by-catch and the infauna. Physical and chemical characteristics were investigated by looking at the sediment properties, bottom temperature and depth. The main factors effecting the distribution of demersal assemblages were found to be depth and geographical location (Biagi *et al.*, 2002, Dimech *et al.*, 2005). Temperature was also found to be important but temperature is directly dependent on depth since as the depth increases temperature decreases. Although a relationship was found between the demersal assemblages and certain habitat characteristics, the discarded by-catch species (most of which were macrobenthos) showed a stronger association with the habitat characteristics across the study area. Most of the discarded by-catch species are prey items for the target species. A comparison of the commercial and the non-target components showed that commercial assemblages residing in different geographical locations may be feeding on two different benthic assemblages which may imply different diets for the same species in different geographic locations and thus feeding habits would depend on the availability of prey species (Konstantinos *et al.*, 2002). The infauna was not found to be correlated in any way with the sediment characteristics but this may be due to a sampling artefact. The infauna had a very low abundance in the sampling replicates and this resulted in difficult comparisons. The low abundance of infauna in the replicate samples was due to the oligotrophic conditions in the deep waters investigated. Probably a more intensive sampling of the infauna would have yielded better results but this would require a large number of replicates. Using a longer time series, larger depth ranges and more replicate stations (chapter 3) the demersal assemblages were classified into four groups with depth and temperature being the environmental factors responsible for the differences between the assemblages. Probably temperature and not depth is the most important factor, since species which were found below certain depths in Maltese waters occur at much shallow depths in other areas such as the north Atlantic. For example *Nephrops norvegicus* started appearing in the samples at ca. 300 m and was common at ca. 400 m in Maltese waters but it is common at ca. 50 m in the North Atlantic waters due to lower temperatures at this depth. The sediment physical and chemical characteristics were much less important in structuring the four assemblage types. Differences in environmental characteristics were also not detected between areas with different levels of trawling pressure when stations inside the FMZ were compared with stations outside the FMZ.

6.2 Conservation benefits of the Fisheries Management Zone (Chapters 3, 4 and 5)

In the chapters 3 and 4 I attempted to assess the conservation benefits of the FMZ by looking in detail at the demersal communities on the depth strata identified. In chapter 3 conservation benefits of the FMZ were detected only for the continental shelf, with no benefits for the other depth ranges.

The benefits on the continental shelf were due to lower fishing pressure since trawling effort is very limited on the continental shelf inside the FMZ. Only 15 trawlers that are restricted in power and length by regulation (Council of the European Union, 2004; 2006) are allowed to fish in the FMZ, while there are no legal restrictions on trawling outside the zone. Furthermore, most of the trawlers that fish inside the zone target red shrimp *Aristaeomorpha foliacea* at a depth ca. 600 m. Species groups sensitive to trawling, such as elasmobranchs (for example, *Scyliorhinus canicula* and *Raja clavata*), were very common inside the zone, and practically absent outside the FMZ. These species were also those most responsible for the difference between the inside and outside continental shelf areas. The analysis of the size-spectra also indicated that elasmobranchs were larger in size inside the FMZ indicating a clear impact on the community of elasmobranchs in the outside stations. There was also twice the biomass and abundance inside the FMZ than the outside for the continental shelf area.

However from the analysis in chapter 3 there was a lack of differences between the inside and outside stations of the FMZ in the depth strata other than the continental shelf. This was probably because the stations sampled inside the FMZ are commercially trawled and hence comparison between the inside and outside stations did not give different results since the inside stations were already impacted by the fishing activities. In the study period of chapters 2 and 3 only stations that are commercially trawled were sampled inside the FMZ due to lack of knowledge on trawlable areas inside the FMZ. Trawling in new areas requires intensive scouting and this is especially relevant for the Maltese bottoms because there are many natural and artificial areas were trawling is not possible. The few attempts made to identify new trawlable areas in the Maltese FMZ prior to 2007 resulted in the loss of part or all of the gear with any equipment (e.g tempreture probe) attached to it. To determine conservation benefits of the FMZ on the deep water (500 – 800 m) MEDITS depth stratum in 2007 (chapter 4) intensive scouting was done to find new trawlable areas that are flat and free of obstacles. In order to avoid too many problems in the research survey only this depth stratum was selected for scouting and then sampling. This depth stratum was also selected since there is a lack of knowledge in the Mediterranean at these depth ranges and it is also the most import target catch for the commercial Mediterranean trawl fleet targeting red shrimps (Levi *et al.*, 1998; Papaconstantinou and Farrugio, 2000). The sampling was designed to sample fished and un-fished sites and then compare the two areas within the FMZ. The results were that un-fished sites (chapter 4) had much higher abundance and biomass with a more diverse community while the fished sites had a community dominated by opportunistic decapod crustaceans. The simple methods to assess the populations also showed that species with different life histories responded differently to the trawling activities.

Relatively sedentary species like *N. norvegicus* and *H. dactylopterus dactylopterus* showed a low resilence to trawling and species with a fast population growth and opportunistic characteristics showed high resilience to trawling (*P. martia* and *A. foliacea*). Scavenging species like *G. melastomus* seem to be moderately affected. The results suggest that present levels of recruitment for the populations examined in the trawled areas are maintained by populations in areas protected from trawling (which is likely to represent the highest cause of mortality in the first age-groups of Mediterranean bottom fishes and shrimps), both natural protected areas such as the rough bottoms and deep water coral reefs surrounding Malta (Schembri *et al.*, 2007), and legally protected areas such as the FAD fishery grounds (Pace *et al.*, 2007), World War II ammunition dumping sites and wrecks (pers. observation).

In Chapter 5 the perceptions of the recreational, part-time and full time commercial fishers was examined to get an idea of what fishers think is the situation of the local stocks. There was a general negative perception of the fishers on the conservation value of the FMZ on fish stocks. However in contrast to pelagic fishers, fishers fishing strictly for demersal resources such as trawlers and netters had an overall neutral response and may either perceive slightly the benefits of the conservation area or have been accustomed to any benefits the FMZ might have since these fishers have been fishing in the FMZ for a large number of years. Bottom trawlers and netters also seem to have the most incentive towards property rights, since the stocks they target are not migratory and therefore remain within the FMZ. Recreational fishers also perceived the benefits of the FMZ. The overall negative response to the FMZ may be affected by the decrease in landings of pelagic and migratory fish, which by their own nature are not protected by the FMZ. Furthermore the general negative fishers' perception of the FMZ may be confounded by their knowledge on the coastal fish stocks, which drastically reduced in the last couple of decades due to over fishing in coastal areas both by commercial and recreational fishers. In chapters 3 and 4 coastal and inshore resources within the FMZ were not assessed due to lack of data and this study focused more with offshore deep waters for which the original aim of the FMZ was set up. The results from the chapter 5 may seem to be in contrast with the results from chapters 3 and 4 but when one takes into account the perceptions of the recreational fishers and the demersal fishers the conservation area has its benefits for offshore demersal resources.

6.3 Recommendations for future research and management proposals

Overall the conclusions from the studies undertaken indicate conservation benefits for the demersal resources in certain areas within the FMZ. The question arises as to what extent these conservation benefits are? Is the conservation effect equivalent for all the demersal species? Are there any spill-over effects for commercial important species? And if yes how much important are these for the fish stocks in the Sicily channel?

A recent stock assessment exercise on hake (*Merluccius merluccius*) in the GFCM geographical sub-areas 15 (Maltese waters) and 16 (South of Sicily) has shown that the stock is overexploited (Anon. 2008) so one may argue that the conservation area is not having the desired effect on the hake stock in the Siciliy channel. This effect might be expected for hake since although it is a demersal species hake can cover large distances. Size of the protection area has been shown to be important for the conservation of species (Claudet *et al.*, 2008) and in the case of hake the size of the FMZ seem not to be large enough for the protection of this species. However apart from the size of conservation zone, the protection of 'essential fish habitats' such as nursery areas and spawning grounds is probably more important, but first these have to be identified and any legalized protection on these areas needs to be assessed. For commercial species which cover smaller distances and are more associated to the area, for example red mullet (*Mullus barbatus*) the conservation benefits of the FMZ and its importance to fish stocks may be different and this also needs to be assessed.

With respect to management actions the Veterinary Affairs and Fisheries Division in Malta needs to take into consideration the research findings from this study and future ones. Apart from the existing regulations specific to the FMZ (EC 813 /2004) and to regulations in the Mediterranean in general (EC 1967/2006) the current zoning system in the FMZ needs to be revised that includes the relocation of the the current authorised trawling grounds that are either not trawlable or where 'essential fish habitats' and habitats protected by the habitats directive exist. Enforcement and control of the existing and future legislation is also vital in order to have the maximum benefit for the sustainable exploitation of fisheries resources and the protection of essential habitats. However the observance of the code rules and an understanding of a sustainable exploitation of fishery resources and environmentally friendly code of behavior should also be pursued mostly with the aid of communication activities and environmental education. In this regard, it should be remembered that even though they may be recorded long afterwards, results achieved through environmental education programs are more effective and sustainable than the effects of control and surveillance system. Conservation awareness activities can produce results over the long term, therefore a system for the avoidance of infringements of adopted protection levels can considerably avoid to compromise the FMZ resources.

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Appendix I

Questionnare used during the socio-economic survey (chapter 5).

EMPAFISH Questionnaire on Commercial Fishing

Date : _____
MPA Name : _______

YOUR FISHING ACTIVITY

Name and registration number of your vessel: _____
Registration harbour : _____
Where do you live ? Town :___________ County / Region :_____________

Are you: Owner of your vessel ☐ Onboard captain ☐ Crewmember ☐
Your enterprise owns: only this vessel ☐ several vessels ☐
Year of birth: _______
Date you started fishing: ______

What are the main technical features of your vessel :

Length	______	Meters	or	______	Feet
Power	______	KW	or	______	Horses
Capacity	______	T			
Date of purchase	______	**Year of construction**		______	

Among the following gears, could you please ordonate the gears you are using, from the most important (1) to the less (2, 3, ...). Leave a blanck when you are not using one of these gears.

Trawl	☐	Lamparo	☐	Dredges	☐
Senne	☐	Surface longline	☐	Pots	☐
Trammel	☐	Bottom longline	☐	Other (specify) :	☐
Nets	☐	Hook and line	☐	_________________	

According to your estimation, what is the present second hand market value of your vessel (including fishing gears and all electronic equipment)? ______€

How far from the coast is your usual longest trip at sea: ______miles

What are the main determinants of your choice of a fishing area? Could you please ordonate these determinants from the most important (1) to the less (2, 3, ...)?

Small distance to the port	☐	Your experience	☐
Resources abundance	☐	Other vessels do fishing in this area	☐
Regulations	☐	Small distance to a protected area	☐
Weather	☐	Other (specify) : ____________	☐

Are you sometimes fishing in the authorised fishing zone of the protected area ? ☐Yes ☐No
If Yes, what part of your total fishing time? ______%
If Not, how far from the protected area do you usually fish? ______Miles

Annual number of engine operating hours? ______ hours

Yearly number of days at sea? ______ days

Average duration of a trip at sea (hours) ?

When fishing inside the MPA	When fishing outside the MPA
_____hours	_____hours

Total number of crew members (equivalent to full time jobs)? ______ persons

Fishing seasons:

	Gears	Targeted species
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		

ASSESSMENT OF YOUR COSTS

Once the catches have been sold, what expenses do you remove from the sales amount before sharing wages?
☐Fuel ☐Subsistence ☐Ice ☐Bait ☐Lubricant ☐Other (specify)

In your sharing system, what is the share of the total crew ? ______ %

Annual fixed costs:

	Euros / year
Boat (maintenance and repairs, including engine)	
Fishing gears (maintenance and replacement)	
Other fixed costs (harbour dues, licence, insurance, management costs,...)	
Total	

What are your usual selling costs (harbour, auction... taxes), in euros? ______ €

Annual fuel and lubricant consumption

	Quantity (litres/year)	Value (€/year)
Fuel		
Lubricant		

What is the cost of fuelling once? ______ €
How many trips at sea can you make with it? ______ Trips

Variable costs (i.e. running costs that are approximately proportional to the number of trips):

	For one trip (€ / trip)	**Per year** (€ / year)
Fuel and lubricant		
subsistence		
ice		
bait		

Other variable costs (please precise______)		

According to your estimation, what is the minimum value / quantity of landings required to balance your variable costs (break-even point) for one trip ? ______ / trip

Minimum quantity of landings of the main target species (kg/trip)	Minimum value of landings (€/trip)
______ kg	______ €

ASSESSMENT OF YOUR EARNINGS

Could you give us an estimation of your total catches per year (all species)? ______ Tons
What percentage of your catches comes from the authorised fishing zone of the protected area? ______%

Catches :

Name of targeted species	Season (month)	Quantity (Tons.)	% catches from the authorised fishing zone of the MPA	Average price (€/kg)

Could you give us an assessment of the annual value of your landings? ______€

Since the creation of the marine protected area, your gross earnings have:
☐ Increased ☐ Been stable ☐ Decreased

What could explain the evolution in your gross earnings?
☐ You have changed your fishing strategy
☐ The restriction of the areas where fishing is authorised (following the creation of the MPA)
☐ The resources abundance
☐ A modification of the catches' prices
☐ Regulation
☐ Other (specify)

Do you have other non fishing income in your household? : ☐ Yes ☐ No
If Yes, could you precise:
- in which activity : ____________
- the time dedicated to this activity : ______% of your working time
- the annual income from this activity: ______% of annual total income
- what are the reasons to this activity ?
  ☐ Impossible to fish (lack of resources, weather, protected areas…)
  ☐ Other activities are more profitable (tourism activities, sport fishing, …)
  ☐ For pleasure: you enjoy practicing other activities
  ☐ Other (please specify)

PERCEPTION OF THE MARINE PROTECTED AREAS AND FISHING STRATEGIES:

On the whole, what would you say is the influence of the protected area on your fishing activity?
☐ Very good ☐ Good ☐ No impact ☐ Bad ☐ Very bad

What do you think of the following assertions?

	Fully agree	Rather agree	Rather disagree	Fully disagree	Don't know
The FMZ helps protecting biodiversity					
The FMZ helps enhancing fish abundance (inside the no-take zone)					
The FMZ helps enhancing fish abundance (out of the no-take zone)					
The FMZ helps enhancing catches					
The FMZ helps decreasing running costs					
The FMZ profits mainly to professional fishing					
The FMZ profits mainly to recreational fishing					
The FMZ profits mainly to scuba-diving					
The zoning system of the FMZ helps reducing use conflicts					
The FMZ helps reducing poaching and illegal fishing					
The FMZ has a favourable influence on the local economy					

How did your fishing effort developed since the creation of the protected area ?

☐ No change
☐ It increased
☐ It decreased
☐ It moved towards other activities not related to fishing

Did the creation of the protected area influence your fishing strategies? ☐ Yes ☐ No

If Yes, how?

☐ You have moved your fishing effort towards other species
☐ You have moved your fishing effort towards other fishing areas
☐ You have moved your fishing effort along the zone close to the protected area
☐ You have moved your fishing effort on other fishing gears

How does coexistence with other users work?

	Good cooperation	Conflict	No contact
Other professional fishers			
Recreational fishers			
Spear fishers			
Diving centres			
Jet ski			
Surfers, windsurfers, kite-surfers…			
Other users (*please precise*)			

Thank your for your cooperation.

Appendix II - Short publications and poster presentations

DEMERSAL ASSEMBLAGES ON DEEP WATER TRAWLING GROUNDS OFF THE MALTESE ISLANDS: MANAGEMENT IMPLICATIONS

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Abstract

Data from three consecutive years of trawl surveys were used to characterise the demersal assemblages present on trawling grounds around the Maltese Islands, (Central Mediterranean) in water ranging from 85m to 800m depth. Five different assemblages were present which seemed related to depth zones that do not coincide with those sampled in existing stock assessment programmes. It is therefore clear that the depth strata sampled in such programmes need to be revised to make them more biologically relevant and to achieve a better sampling representation of each assemblage type.

Keywords : Demersal, Deep Waters, Fisheries, Stock Assessment, Trawl Surveys.

Introduction

The modern trend in the management of fish stocks is âĂŸecosystem-based fisheries management', where fish stocks are no longer considered in isolation but as one component of an integrated ecosystem [1]. In turn, such an approach requires a good knowledge of the constituents of the system. Bottom trawling is an important component of many Mediterranean fisheries, being responsible for a high share of total catches and, in many cases, yielding the highest earnings among all the fishing sub-sectors. In the Mediterranean, bottoms are trawled for commercial fishing at depths ranging from 50 to 800m [2]. We studied the spatial distribution of demersal resources on muddy bottoms in the depth range from 80m to 800m within the General Fisheries Commission for the Mediterranean (GFCM) geographical sub-unit 15, and assessed management implications of our results.

Methods

Samples were collected from trawling grounds off the Maltese islands within the GFCM geographical sub-unit 15 as part of the ongoing MEDITS trawl survey programme. Otter trawl samples were collected in June-July of 2003, 2004 and 2005 from 45 stations located at different depths between 80m and 800m. Each haul lasted for ca 45 minutes, depending on the depth and substratum type, and trawl speed was ca 3 knots; the gear used was IFREMER GOC 73 [3] and consisted of a 40m long and 22m wide trawl net with a 1-2m vertical opening and a cod end stretched mesh size of 20mm. The entire faunal component from each haul was sorted, identified, weighed and counted. The data for each station were standardised per square kilometre, and were analysed using classification and ordination techniques. Species whose percentage biomass was less than 0.01% were removed from these analyses. Agglomerative hierarchical clustering followed by non-metric multidimensional scaling (nMDS) ordination was then applied on a similarity matrix constructed from the fourth-root transformed data using the Bray-Curtis similarity measure, using the PRIMER 6 software [4]. Since the biomass data yielded more detailed and clearer results than abundance data, and the former is presented in this paper.

Results and discussion

A total of 552,963 live individuals (22,887 kg) comprising 189 different species (26 elasmobranchs, 111 teleosts, 26 decapods and 26 molluscs) were identified, of which teleosts were the largest component in terms of both abundance and biomass.Cluster analysis and nMDS ordination of the species biomass data resulted in five main clusters at a similarity of 46% (Fig.1). These clusters correspond to two sets of outer continental shelf stations, those from the continental shelf slope (140 - 273m), those from the shelf break (240 - 440 m) and those from the deep slope (466 - 701m) stations.

In general, the difference in assemblage structure increases with depth, with the transition from one assemblage to the next being more gradual at shallower depths and sharper as the depth increases. The differences between the continental shelf assemblages (Outer shelf A, Outer shelf B, Shelf break) were mainly quantitative, but were both quantitative and qualitative between the outer and shelf break assemblages and the upper slope assemblages, and between the upper slope assemblages and those of the deep slope.

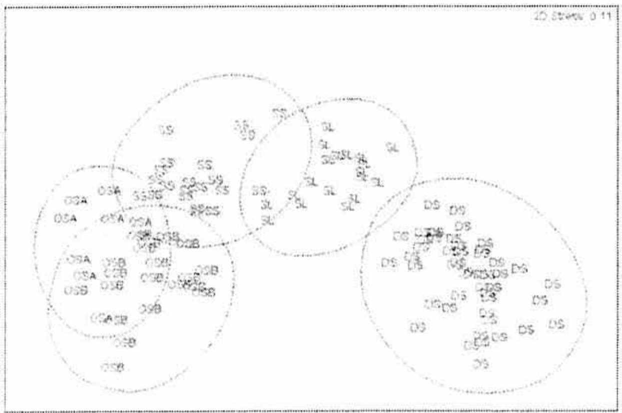

Fig. 1. Non-metric multidimensional scaling (nMDS) plot for the sampling stations for all the three years, based on biomass. The ovals enclose the groups generated by cluster analysis. OSA - Outer shelf A; OSB - Outer shelf B; SS - Shelf break; SL - Shallow slope; DS - Deep slope.

Based on these results the fishery resources of Maltese trawling grounds are stratified in four main depth ranges: 80-160m (outer continental shelf: two subgroups), 160-270m (shelf break), 270-440m (upper slope), and 440-800m (deep slope). These strata do not coincide with those sampled in existing stock assessment programmes, which were set up without reference to benthic/demersal assemblage structure and its relation to depth. It is therefore clear that the depth strata sampled in such programmes need revision to make them more biologically relevant and in order to have a better sampling representation of each assemblage type. There would be substantial benefit in further regional analyses of assemblage structure to detect the impact of various fishing practices on the benthic/demersal assemblages both spatially and temporally, and if any changes found are related to the spatial and temporal effort of the fishing fleet.

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ROLE OF ENVIRONMENTAL VARIABLES IN STRUCTURING DEMERSAL ASSEMBLAGES ON TRAWLED BOTTOMS ON THE MALTESE CONTINENTAL SHELF.

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Abstract

Demersal assemblages from trawl surveys made at depths of 45-800m in trawled areas within the 25NM Fisheries Management Zone round the Maltese Islands were related to environmental characteristics on the seabed. Depth, temperature, and mean grain size all affected the structure of the demersal assemblages but depth and temperature gradient were overall the most important in that order: while mean grain size seemed more important for relatively shallow bottoms (<80m) than for deep ones.

Keywords : Demersal, Fisheries, Sediments, Temperature, Trawl Surveys.

Introduction

Prior to joining the European Union, Malta managed a 25 nautical mile Exclusive Fishing Zone. Post-EU membership, Malta was allowed to retain this zone, which covers an area of 10,700 km^2, as a Fisheries Management Zone (FMZ) as there are indications that demersal fishery stocks within the zone are distinct from those outside [1]. For shallow shelf resources (<200 m) within the FMZ, adult populations of demersal fish are believed to be isolated to some degree from adjacent populations and exchange of adult individuals between these populations may be limited. At present, there is little information on the distribution of biological assemblages in relation to environmental variables within the Maltese FMZ, even if such information is essential for the management of living resources. A programme of research to address this is being implemented.

Methods

Otter trawl samples were collected from stations at depths between 45m and 800m distributed within the Malta 25NM FMZ in the summer of 2003, 2004 and 2005 as part of the ongoing MEDITS trawl survey programme. Samples were collected with a semipelagic experimental trawl net (IFREMER GOC 73) and each haul lasted for ca 45 minutes, depending on the depth and substratum type; trawl speed was ca 3 knots. Bottom temperature was measured with a temperature probe attached to the net. The entire catch from each haul was sorted, and the fauna were identified and counted. Samples for sediment analyses were collected in 2004 and 2005 from a limited number of stations using a 0.0625mÂš box corer. Sediment granulometry was determined according to the procedures described by Buchanan [2].

The macrofaunal data were analysed by first constructing a similarity matrix from the root-root transformed biomass data using the Bray-Curtis similarity measure and then applying non-metric multidimensional scaling (nMDS) ordination [3]. Relationships between measured abiotic characteristics (depth, temperature, mean grain size) and demersal assemblages were determined using the BIOENV procedure and by superimposing scaled individual variables onto the sample locations on the two-dimensional nMDS ordination plots. All the analyses were made using the PRIMER 6 statistical software package [3].

Results and Discussions

The visual correlations between the environmental variables and the groups generated by the nMDS ordination indicate that all three physical parameters seemed to play a role in structuring the demersal assemblages. The BIOENV correlation analyses gave relatively high values of Spearman's coefficient for depth, temperature, and to a lesser extent, for mean grain size. (Figs 1 and 2).

The most important environmental variable responsible for the observed patterns of change in community structure was depth. Depth has also been shown to be the main factor determining the distribution of marine fauna in other areas of the Mediterranean [4]. Temperature was second in importance, while the correlation coefficient for mean grain size was relatively low when compared to the coefficients for depth and temperature. While mean grain size explained well the distribution of the relatively shallow water stations (46-82m), it was not as important in structuring the deeper water assemblages. In summary, the depth and temperature gradients, with their accompanying environmental and biological changes, are the main factors responsible for the patterns in community structure observed.

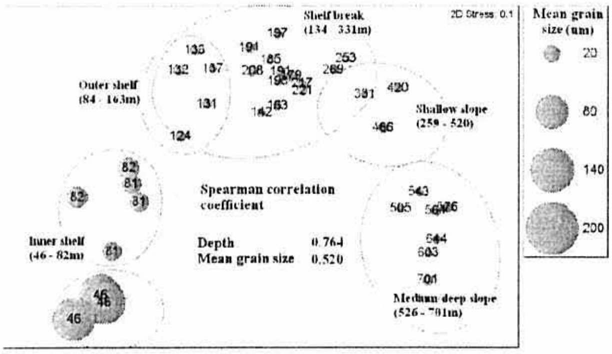

Fig. 1. Non-metric multidimensional scaling (nMDS) plot for the sampling stations from 2004 and 2005, based on biomass with superimposed scaled values of mean grain size (μm). The numbers on each station position give the mean depth for that station.

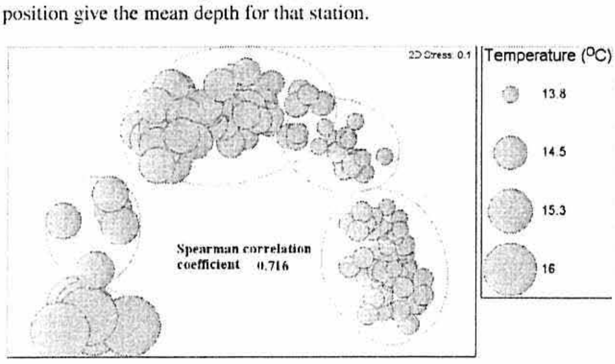

Fig. 2. nMDS plot with superimposed scaled values of temperature (°C) for all three years (2003, 2004 and 2005).

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Relationship between commercial & non-commercial species and abiotic characteristics in trawled muddy habitats on the Maltese continental shelf.

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Introduction.

Prior to joining the European Union, Malta managed a 25 nautical mile Exclusive Fishing Zone (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 km², 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. Therefore the shelf seas around Malta can be regarded as an independent management unit for demersal resources. 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.

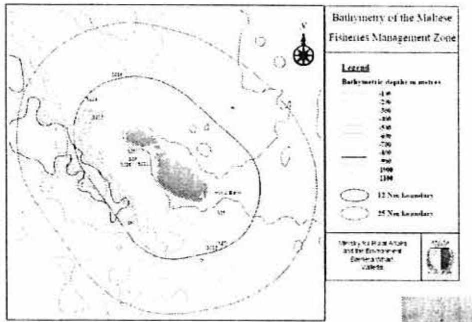

Fig 1. Map of the Maltese islands showing the ten sampling stations

The box corer being deployed from the *RV Sant'Anna*

Contents of the trawl being emptied on the deck

Sampling methodology.

The present study was conducted in the Maltese 25 nm FMZ as part of the ongoing MEDITS trawl survey programme (Fig. 1). Otter trawl samples were collected in summer 2004 from stations located at different depths between 100m and 300m on muddy bottoms. Sampling was undertaken on board the *RV Sant' Anna*. Each trawl haul lasted for c. 45 minutes, depending on the depth and substratum type and trawl speed was c. 6 knots; a semipelagic experimental trawl net (IFREMER GOC 73) was used. The entire faunal component from each haul was sorted into commercial and non-commercial (by-catch) components after which the fauna were identified and counted. Samples for infauna and sediment analyses were collected using a 0.0625m² box corer. 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 root-root transformed abundance data using the Bray-Curtis similarity measure; non-metric multidimensional scaling (nMDS) ordination (Clarke & Warwick, 1994) 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, 1994). Relationships between measured abiotic characteristics and faunal assemblages were determined by superimposing individual variables onto the sample locations on the two dimensional nMDS ordination plots (Clarke & Warwick, 1994).

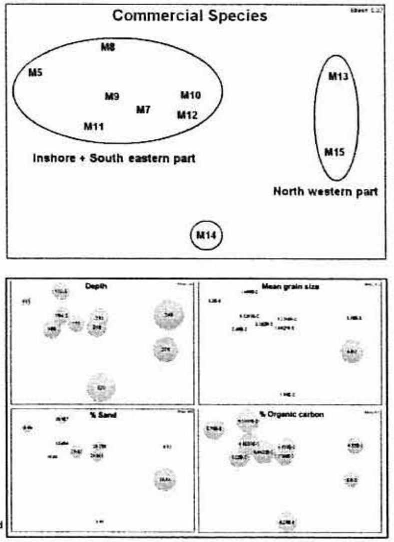

Fig 2. Non-metric multidimensional scaling (MDS) plot for the ten sampling stations after double square root transformed species abundance data from the trawl commercial species catch using the Bray-Curtis similarity measure. Expanded plots of scaled values of depth, mean grain size, % sand, % organic carbon are also shown.

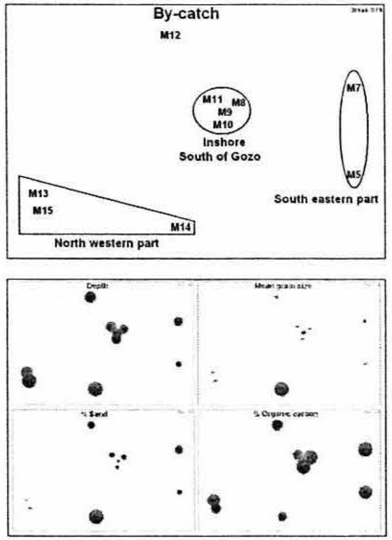

Fig 3. Non-metric multidimensional scaling (MDS) plot for the ten sampling stations after double square root transformed species abundance data from the trawl by-catch species using the Bray-Curtis similarity measure. Scaled values of depth, mean grain size, % sand, % organic carbon are also shown.

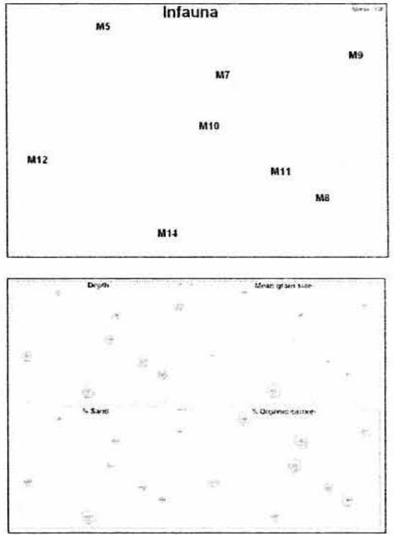

Fig 4. Non-metric multidimensional scaling (MDS) plot for eight sampling stations after double square root transformed species abundance data from the mud infauna using the Bray-Curtis similarity measure. Scaled values of depth, mean grain size, % sand, % organic carbon are also shown.

Table 1. The top ten commercial species from the SIMPER species list, which contributed consistently to the dissimilarity between the inshore + SE part and the NW part stations (Clarke & Warwick, 1994)

Taxon name	Mean abundance	
	Inshore + SE part	NW part
Aristeomorpha foliacea	0.0	4568.5
Trachurus trachurus	4493.6	0.0
Illex coindetii	1813.0	0.0
Nephrops norvegicus	0.0	855.5
Mullus barbatus	606.3	0
Galeus melastomus	0.0	236.0
Phycis blennoides	2.9	237.5
Citharus linguatula	401.3	0.0
Trisopterus minutus capelanus	352.0	0.0
Aspitrigla cuculus	201.4	0.0

Table 2. The top ten by-catch species from the SIMPER species list, which contributed consistently to the dissimilarity between the different geographical locations (Clarke & Warwick, 1994)

Taxon name	Mean abundance		
	Inshore	SE	NW
Leptometra phalangium	0.0	514.00	2.00
Antedon mediterranea	0.0	6.50	0.00
Parapenaeus longirostris (juv.)	16.75	210.00	7.67
Cidaris cidaris	1.0	10.50	0.33
Latreilla elegans	1.25	6.00	0.00
Sepia orbignyana	1.25	0.00	0.00
Illex coindetii (juv.)	16.75	32.00	0.00
Plesionika heterocarpus	0.00	0.00	19.33
Sergestes corniculum	0.00	0.00	17.33
Pasiphaea sivado	0.00	0.00	6.67

The contents of a typical haul before sorting of commercial species and by-catch

Results

The commercial species were separated into two major distinct groups of stations: the inshore and south-eastern stations and the north-western deeper stations (Fig. 2). The inshore and south-eastern sites were dominated by *Trachurus trachurus, Illex coindetti and Mullus barbatus*, while the north-western stations were dominated by typically deep water species such as *Aristeomorpha foliacea*, *Nephrops norvegicus* and *Galeus melastomus* (Table 1). 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 was ranged from 200 – 350 m.

The by-catch species showed a similar pattern with respect to the inshore stations (Fig. 3), but there was a greater biological variability for the offshore stations (Table 2). There was also strong correlation of the offshore stations with geographical position: stations off the north-western coast were grouped together, as were those off the south-eastern parts of the Maltese islands. The infauna was the component of the community that had the greatest spatial variation (Fig 4) 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.

Conclusions.

For the commercial species two assemblages were apparent that were largely influenced by geographic location and depth. The by-catch component showed similar patterns although these were less clear while the infauna was spatially the most variable component and varied the most around the Maltese islands

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Structure of demersal assemblages under different intensities of trawling pressure on the continental shelf around the Maltese Islands (Central Mediterranean).

MEDSUDMED

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BANGOR

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Introduction

In response to the current trend of declining fish stocks world wide, fisheries managers are seeking new tools to enable them to achieve sustainable use of marine resources. The creation of fisheries reserves and marine protected areas (MPAs) is one such management option that may help to reduce declining stocks. In the present work we studied the spatial and temporal relationships between the structure of the demersal assemblages, sediment characteristics, and the distribution of demersal resources on the Maltese continental shelf within the 25-nautical mile Fisheries Management Zone (FMZ) around Malta (a fisheries reserve) and in the sea area immediately outside this (where fishing is unregulated). The Maltese FMZ was originally set up in 1971 as an Exclusive Fishing Zone managed through a strict licensing scheme designed to keep large scale industrial fishing, such as trawling, at a minimum; this management area was retained after Malta joined the European Union in 2004 as a 'Fisheries Management Zone' with a new set of regulations, which however are still aimed at safeguarding fishery stocks within the zone (Camilleri, 2003; Council of the European Union, 2004).

Fig. 1 Map of the study area showing the boundary of the Maltese 25NM Fisheries Management Zone (FMZ) (the oval round Malta). The red circles mark the position of the trawl sampling stations outside the 25NM zone while the blue stations mark the stations inside. The 200 (yellow) and 400 (orange) metre depth contours are also shown.

Methods

Experimental otter trawl samples were collected by the RV Sant'Anna in June/July of 2003, 2004 and 2005 from muddy bottoms at depths of 80-170m on the continental shelf around the Maltese Islands. Two stations (3 replicate samples per station) were located inside the Maltese 25-nautical mile Fisheries Management Zone (FMZ) and eight stations (2-3 replicate samples per station) were outside this zone. Trawling effort, as assessed by satellite tracking of the fishing vessels (Vessel Monitoring System), is negligible at the stations inside the FMZ. Outside the FMZ no legal restrictions on rawling effort exist and the stations sampled here are trawled regularly. The catch from each haul was sorted and the demersal fauna were identified, weighed and counted. The length and weight of all individuals of 34 selected species that included fish, crustaceans and cephalopods, were also recorded. Sediment granulometry and sedimentorganic carbon were estimated from sediment samples collected using a WILDCO® 0.0625m² box-corer. Depth and temperature were measured using a probe attached to the trawl net. Granulometry was determined according to the procedures in Buchanan (1984).

For each group of stations, the following parameters were calculated: Density Index (DI) in N/km², Biomass Index (BI) in kg/km², number of species (S), Shannon-Weiner diversity (*H'*) and mean Pielou's evenness (*J'*). Biomass data for the stations were analysed by first constructing a similarity matrix from the root-root transformed biomass data using the Bray-Curtis similarity measure, and then applying non-metric multidimensional scaling (nMDS) ordination using the PRIMER 6 statistical software package (Clarke & Warwick, 1994).

Size spectra were calculated for inside and outside the 25-nautical mile FMZ based on all the data from each of the three separate years, by using the weights of individuals from all taxonomic groups, including teleosts, elasmobranches, crustaceans and cephalopods. Since different hauls did not sweep equal areas of the bottom because of the large difference in the depth range, weights were standardized per km², after which each individual was assigned to a weight-class ($\log_{10}$ weight in grammes). The data were normalised and the logarithm of the biomass was calculated. Lower and upper size classes were excluded to avoid data artefacts due to poor retention in the gear. Differences in the parameters between the inside and outside stations were tested using the independent sample t-test.

Results and Discussions

Of the univariate indices measured, only the biomass index was significantly different (t-test; P> 0.05) between the 'inside' and 'outside' stations and was highest for the stations inside the Maltese 25-nautical mile FMZ (Table 1). Of the environmental variables measured, percentage organic carbon was also significantly higher (t-test; P> 0.05) in the stations inside the FMZ. The biomass size spectra of all taxonomic groups considered together showed subtle differences between the stations inside and outside the FMZ (Fig. 4); more clear differences were detected when specific taxonomic groups were considered separately. With respect to the biomass size spectra, significant differences between the 'inside' and 'outside' stations were due to elasmobranches (t-test; P> 0.05). Multivariate analysis also clearly differentiated between the 'inside' and 'outside' stations on the basis of biomass (Fig 5).

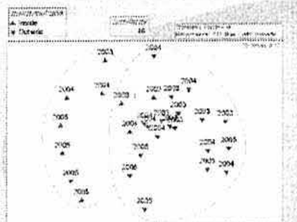


Fig 5. Non-metric multidimensional scaling (nMDS) plot for the sampling stations from 2003, 2004 and 2005, based on BI (kg/km²).

	t	df	P (2-tailed)	Mean Difference	Std. Error Difference
BI X10^? (kg/km²)	[illegible]	27	**0.009**	[illegible]	[illegible]
DI X10^? (N/km²)	[illegible]	27	[illegible]	[illegible]	[illegible]
Number of species (S)	[illegible]	27	[illegible]	[illegible]	[illegible]
H'	[illegible]	27	[illegible]	[illegible]	[illegible]
J'	[illegible]	27	[illegible]	[illegible]	[illegible]
Depth (m)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature (°C)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Median diameter (mm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Organic carbon (%)	[illegible]	[illegible]	**[illegible]**	[illegible]	[illegible]
All Taxa gradient	[illegible]	4	[illegible]	[illegible]	[illegible]
Teleost gradient	[illegible]	4	[illegible]	[illegible]	[illegible]
Elasmobranches gradient	[illegible]	4	**0.029**	[illegible]	[illegible]
Crustacean gradient	[illegible]	3	[illegible]	[illegible]	[illegible]
All Taxa intercept	[illegible]	4	[illegible]	[illegible]	[illegible]
Teleost intercept	[illegible]	4	[illegible]	[illegible]	[illegible]
Elasmobranches intercept	[illegible]	4	**0.004**	[illegible]	[illegible]
Crustacean intercept	[illegible]	3	[illegible]	[illegible]	[illegible]

Table 1. Results of the t-tests for equality of means between the 'inside' and 'outside' stations for the variables measured. Values in bold indicate a significant difference at α = 0.05.

Sicilian fishing fleets regularly trawl the continental shelf outside the 25 NM FMZ since it is very close to the main Sicilian fishing ports. The species composition of samples from inside and outside the FMZ shows that species groups sensitive to trawling, such as elasmobranches (especially, *Scyliorhinus canicula* and *Raja clavata*), were very common inside the FMZ, however, such species were practically absent outside the FMZ. This group was also that most responsible for the difference between the 'inside' and 'outside' stations. For the 'inside' stations analysis of the size spectra also showed that elasmobranches attain larger size inside the FMZ. The continental shelf inside the FMZ has more than twice the biomass and abundance (per unit area) than that outside the FMZ, and reduced biomass and abundance is a common feature of heavily trawled areas (Kaiser and de Groot, 2000).

Fig 2. Mean (± standard error) values of Density Index (DI) in N/km², Biomass Index (BI) in kg/km², number of species (S), Shannon-Weiner diversity (H') and mean Pielou's evenness (J') for the inside and outside stations.

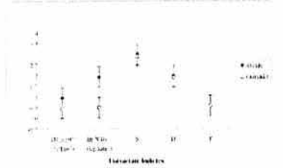
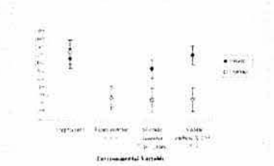


Fig 3. Mean (± standard error) values of the environmental variables measured: depth in m, temperature in °C, median grain size X 10⁻³ in mm, and percent organic carbon X 10² for the 'inside' and 'outside' stations.



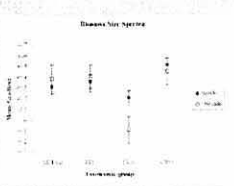
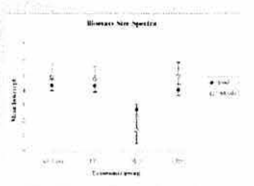


Fig. 4 Differences in the gradient and intercept (± standard error) of the biomass size-spectra for all the taxonomic groups together, and for teleosts (TEL), elasmobranchs (ELA) and crustaceans (CRU) separately, for the 'inside' and 'outside' stations.



Conclusion

Fishing pressure was estimated using the satellite vessel monitoring system (VMS) installed on the trawlers and trawling pressure is likely to be the main factor driving the biological and physical differences between the two groups of stations investigated. The management regime enforced within the previous 25NM Exclusive Fishing Zone by the Maltese government between 1971 and 2004 seems to have been effective in protecting the demersal resource in the fisheries reserve on the continental shelf round Malta, and although the actual regulations pertaining to the FMZ are now different, the management objectives are the same. However, only continuous monitoring will show if the demersal resources continue to benefit from the protection effect of the 25NM Fisheries Management Zone.

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