# Some relevant information on the spatial distribution of demersal resources, benthic biocoenoses and fishing pressure in the Strait of Sicily

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## Abstract

Suggestions for research within the MedSudMed Project are made on the basis of existing information on spatial distribution of demersal resources, benthic biocoenoses and fishing pressure in the Strait of Sicily. Results presented derive mainly from the research carried out at IRMA–CNR from 1985 onwards, mainly on the northern side of the Strait. The co-variation of parameters on a large space- and time-scale is presented as a general approach to understanding how fish stocks react to environmental and fishing impacts. The GIS applications, integrating several kinds of information (resource abundance and demographic data, fish assemblages, biocoenoses, substratum type, hydrographical features), are chosen in order to explore ecological structures and to study "cause and effect" relationships. This information represents the preliminary and necessary knowledge required for the identification of the main demersal stock units and for the sustainable exploitation of shared marine resources in the Strait of Sicily.

## 1. Introduction

The Strait of Sicily appears to be particularly important for fishing, as witnessed by the important fleets operating there and the associated fish production. This is probably one of the most important fishing areas for demersal resources in the Mediterranean. For management purposes, the Strait of Sicily was recently divided into six geographical sub-areas (GSs), in which marine fisheries should be monitored and regulated (FAO, 2001). According to the usual assessment procedures, most of the demersal resources in these GSs were found to be "fully exploited" or "overexploited", 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).

The aim of this paper is to present selected results on different topics of recent work carried out by IRMA–CNR in Mazara del Vallo under its programmes on the evaluation of demersal resources. In the authors' opinion, these results could be relevant to the investigation of the spatial distribution of the demersal resources in the region and contribute to the understanding of how fish populations react to environmental and fishing impacts.

This document should be considered as a contribution to the stimulation of a general discussion during the present expert consultation and not as an exhaustive review of the existing problems of the demersal stocks in the Strait of Sicily.

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## 2. Stock units in the Strait of Sicily

Preliminary information is available on the main stocks of commercial species in the Strait of Sicily.

***Mullus barbatus:*** Although the red mullet is a typical coastal resource, the peculiarity of the Strait of Sicily (two shelves on the Sicilian and African sides separated by deep bottoms and the existence of large offshore banks), together with the distant-water fisheries practised by the Mazara del Vallo trawlers, make *M. barbatus* and its congener, *M. surmuletus*, a stock shared amongst the Strait countries.

Consequently, the knowledge of the red mullet stock distribution in different GSs into which the Strait of Sicily is divided is a main research need.

Levi *et al.* (1992) compared growth curves of *Mullus barbatus* in the Mediterranean, finding significant differences between the red mullet growth on the Sicilian side of the Strait (GSs 15 and 16) and in the Gulf of Gabès (GS 13). Other evidence supporting the existence of separate stocks of red mullet in the central Mediterranean comes from parasitological observations. A large infestation by a trematode of the genus *Stephanostomum* seriously affected the red mullet fishery in Tunisian waters for several months in 1990. No such occurrence was noted in the fish landed at the Sicilian base-ports of the present study area (Levi *et al*. 1993b).

Levi *et al.* (1995a) made other suggestions for the separation of stock units in the Strait of Sicily, on the basis of the independent water masses and circulation systems on the Sicilian and African sides of the Strait.

***Parapenaeus longirostris:*** This deep-water pink shrimp is one of the most evidently shared resources of the Strait of Sicily, with most of the catches being made in deep international waters in the central area. In this respect, a better understanding of the *P. longirostris* stock distribution in the different GSs into which the Strait of Sicily is divided is a principal research need. A preliminary hypothesis on an east–west migration was put forward by Levi *et al.* (1995b), but no specific studies have been carried out to date.

***Merluccius merluccius*:** Considering the existence of distant-water fisheries in the area, an understanding of the hake stock distribution in different GSs in the Strait is highly desirable.

Levi *et al.* (1992) compared the growth curves of *M. merluccius* in the Mediterranean, finding quite a similar pattern in growth on the northern side of the Strait (GSs 15 and 16) and in the Gulf of Gabès (GS 13). Lo Brutto *et al.* (1998) found no evident genetic subdivisions or significant differences in allelic frequency between samples from near Sicily and those from the mid-line established for the exploitation of bottom mineral resources.

More recently, Levi *et al.* (2003a) made electrophoretic, morphometric and growth analyses to test the hypothesis of the existence of a unique hake stock in the study area, which includes part of the North African continental shelf off the Tunisian coast and the shelf off the southern Sicilian coast. The level of genetic variation detected at five selected sample sites was very low. Conversely, morphometric analyses and otolith readings revealed some differentiations at a phenotypic level, mainly in females.

## 2.1 Spatial distribution of relevant biological phases of the main demersal species

Geo-referenced data of the two main relevant phases (recruits and adults) of selected demersal species, collected during the trawl-survey programmes (GRUND and MEDITS), were elaborated in order to obtain a preliminary identification of the spatial distribution of spawning and nurseries areas in the region. All these elaborations used approaches taking into account the likely annual variability in order to relate the observed variation in abundance of organisms to variability in any impact factors, whether of environmental or fishery origin.

Regarding *Mullus barbatus, Illex coindetii* and *Eledone cirrhosa*, distribution maps are available both for recruits and adults, although based on different long time-series, ranging from 2 years for cephalopods to 9 years for *Mullus barbatus*. Concerning *Merluccius merluccius, Phycis blennoides* and *Parapenaeus longirostris*, only the distribution of the juveniles during the first year of life is available.

***Mullus barbatus*:** According to Garofalo *et al.* (2002a), two major and clearly separate spawning areas exist on the northern side of the Strait (GSs 15 and 16). They are located over the Adventure Bank, off the south-western coast of Sicily (GS 16) and over the Malta Bank, between Sicily and the Maltese Islands (GS 15), respectively, at approximately 100 m depth.

Although recruits had a widespread distribution throughout the coastal waters, four main areas, showing high abundance and the almost exclusive presence of recruits, were found within GS 16 (southern coast of Sicily), between 20 and 50 m depth (Figure 1).

Recently, Levi *et al.* (2003b) investigated the stock-recruitment relationship for red mullet on the northern side of the Strait of Sicily, including environmental information in terms of the sea-surface temperature (SST) anomaly as a proxy for oceanographic processes affecting recruitment. Results showed that, for a given level of spawning stock, a higher level of recruitment corresponded to above-average SST during the early life stages (Figure 2).

***Illex coindetii*:** On the basis of the MEDITS spring surveys (1999–2000), Jereb *et al.* (2001) showed that this species was more abundant in the western-central sector of the Strait. It is interesting to note that the numerical abundance observed was remarkably different when considering the two survey years separately: that of spring 2000 being up to ten times more abundant than that of spring 1999. In both years, juveniles were highly concentrated in the central zone. These main nurseries were related to the presence of a frontal zone located approximately in the middle of the area (the Gela Basin), which was evident in both years, although more sharply defined in spring 1999 (Figure 3).

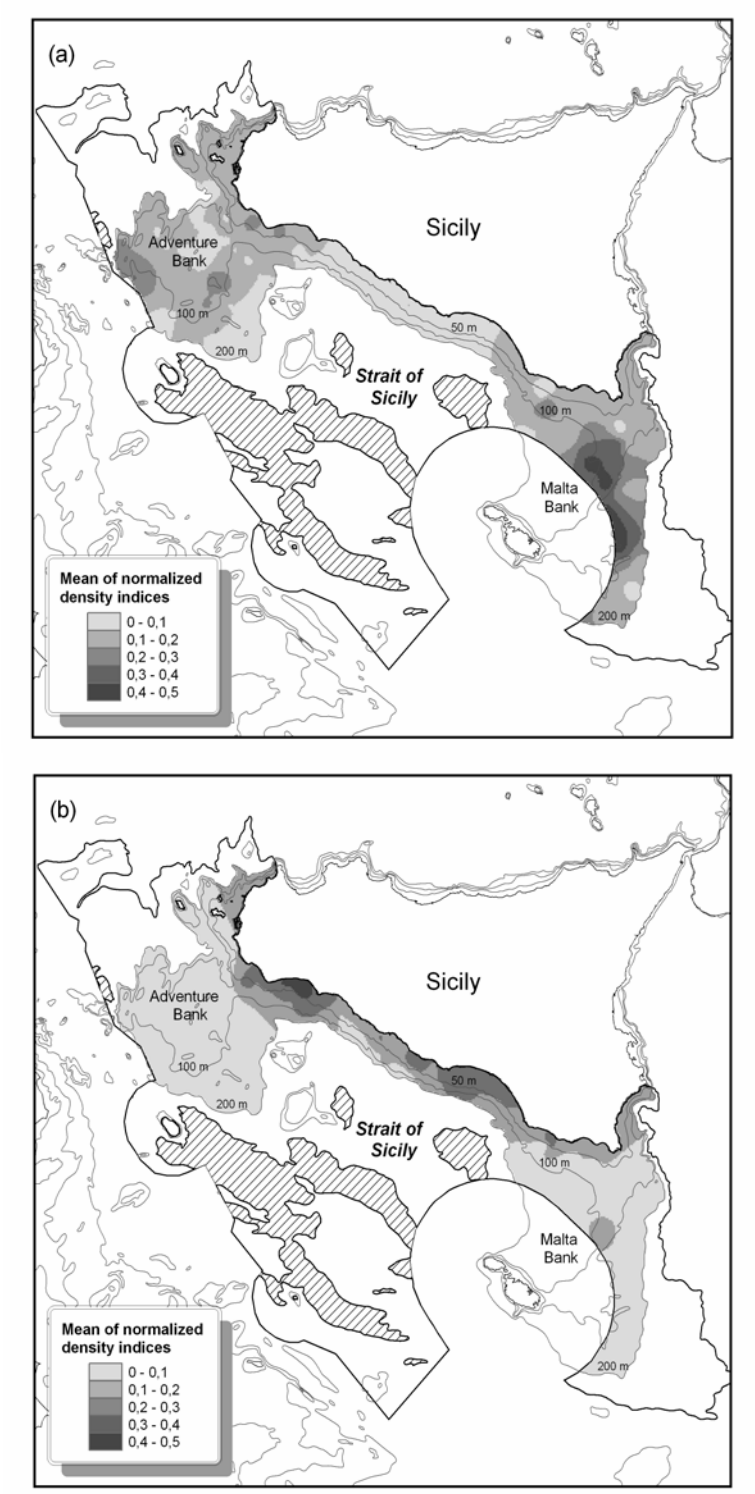


Figure 1. Spawning (top panel - a) and nursery (bottom panel - b) areas of *Mullus barbatus* (from Garofalo *et al.* 2002a)

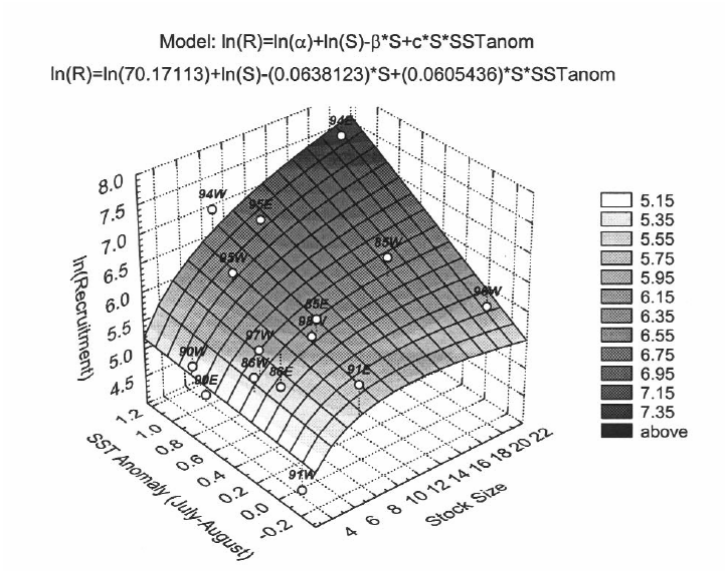


Figure 2. *Mullus barbatus.* Stock–recruitment relationship and environmental factors (from Levi *et al.* 2003b).

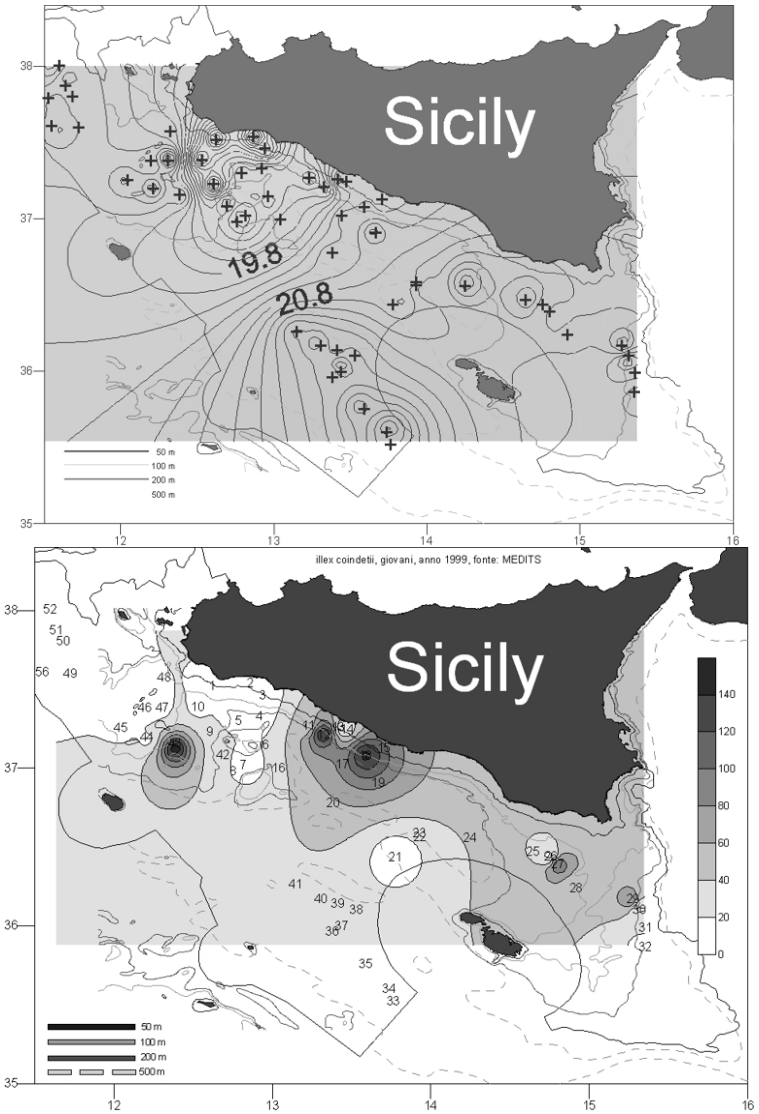


Figure 3. *Illex coindetii*. Frontal system, derived from sea-surface temperature (top panel) and distribution of nursery areas (bottom panel) in the Strait of Sicily (from Jereb *et al.* 2001).

***Eledone cirrhosa*:** According to Jereb *et al.* (2001), no evident relationship was found between adult and juvenile distributions, even though in both years (1999 and 2000), a major concentration of both was observed in the western sector. No striking difference in abundance between the two years' catches was observed; however, *E. cirrhosa* juveniles were considerably more abundant in spring 2000, when an important presence of adults on the Malta Bank (eastern sector) was also detected (Figure 4).

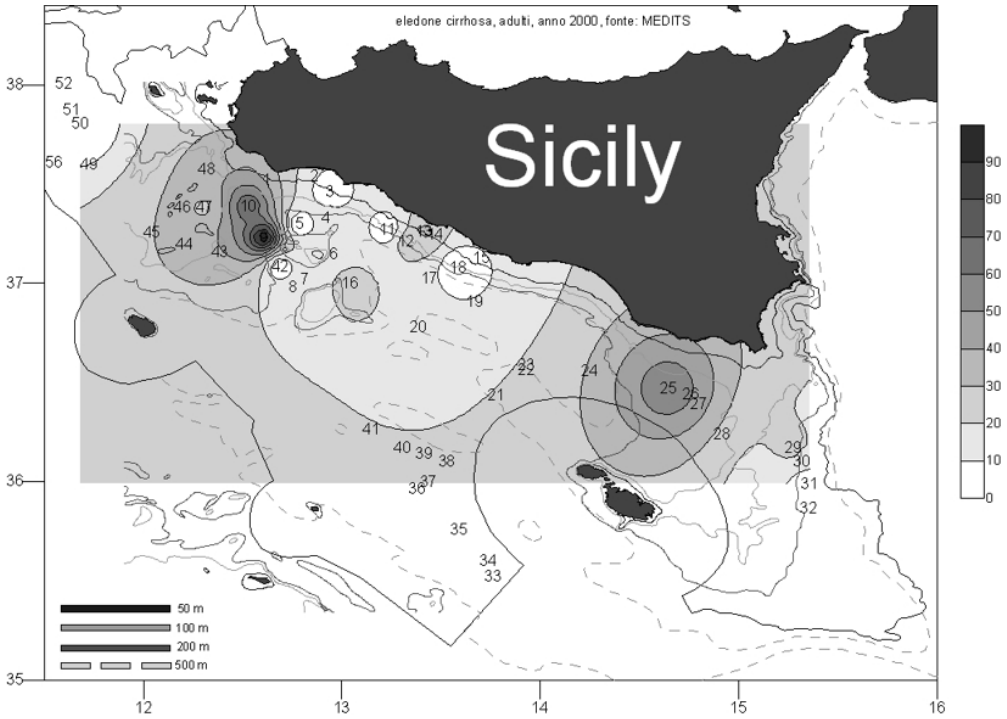


Figure 4. *Eledone cirrhosa.* Distribution of adults (from Jereb *et al.* 2001).

***Parapenaeus longirostris*:** Despite the fact that no maps of interpolated abundance are available for this species, a preliminary geographical representation of nurseries on the northern side of the Strait was provided by Fiorentino *et al.* (2002), within the framework of the MEDITS programme. The presence of nurseries was determined through maps of the hauls characterized by the co-occurrence of a high density (density index of recruits in the 4th quartile) and exclusive presence (i.e. recruits were ≥80% of the number of *P. longirostris* per square kilometre) of recruits in GS 16 (northern side of the Strait of Sicily) drawn up for each year.

During the whole period (1994–1999), 43 out of 336 hauls satisfied the co-occurrence criterion. The annual variability with respect to nurseries was low. One important nursery was located off Capo Rossello, in the western-central part of the area, and another on the eastern side of the Malta Bank, close to 200 m depth (Figure 5).

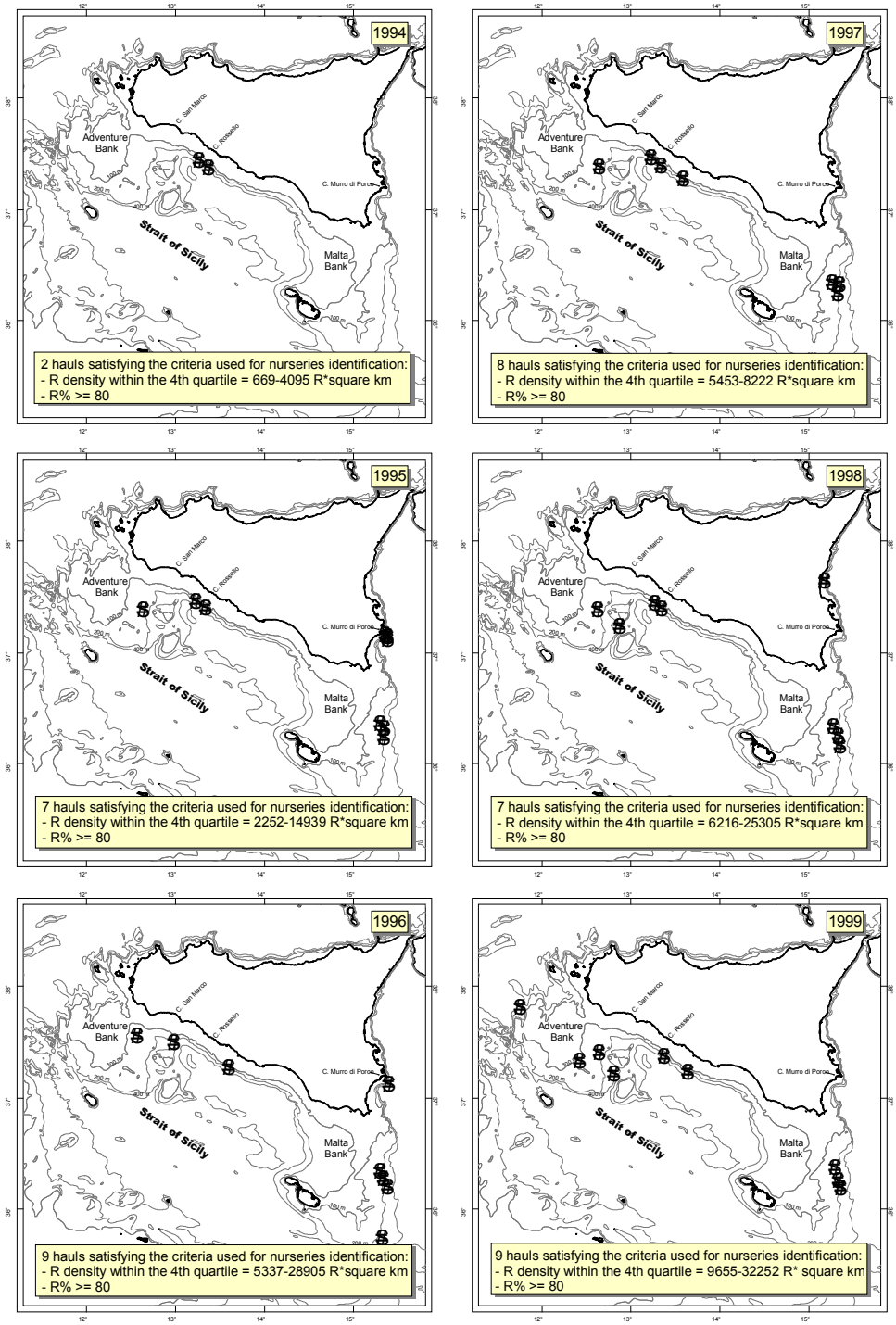


Figure 5. *Parapenaeus longirostris*. Occurrence of recruits, showed by solid dots, in the Strait of Sicily (from Fiorentino *et al.* 2002)

***Merluccius merluccius*:** Preliminary information on the identification of the fish nursery areas in the Strait of Sicily has been derived from Lembo *et al.* (2000), based on 1995 and 1996 MEDITS data. More recently, the spatio-temporal distribution and abundance of hake recruits (0 group) in the Strait of Sicily was studied (Fiorentino *et al.* 2003a). The estimation of the abundance of recruits derived from the MEDITS programme (1994–1999) on the entire

Sicilian side of the Strait of Sicily showed that hake recruitment was quite stable throughout the period of investigation time.

Although some inter-annual variability in the distribution of the nurseries was evident, two stable areas could be identified for *M. merluccius* (Figure 6) which are probably connected to the presence of mesoscale oceanographic processes (Figure 7). These nurseries were located on the eastern side of the Adventure and Malta Banks, mainly between 100 and 200 m depth.

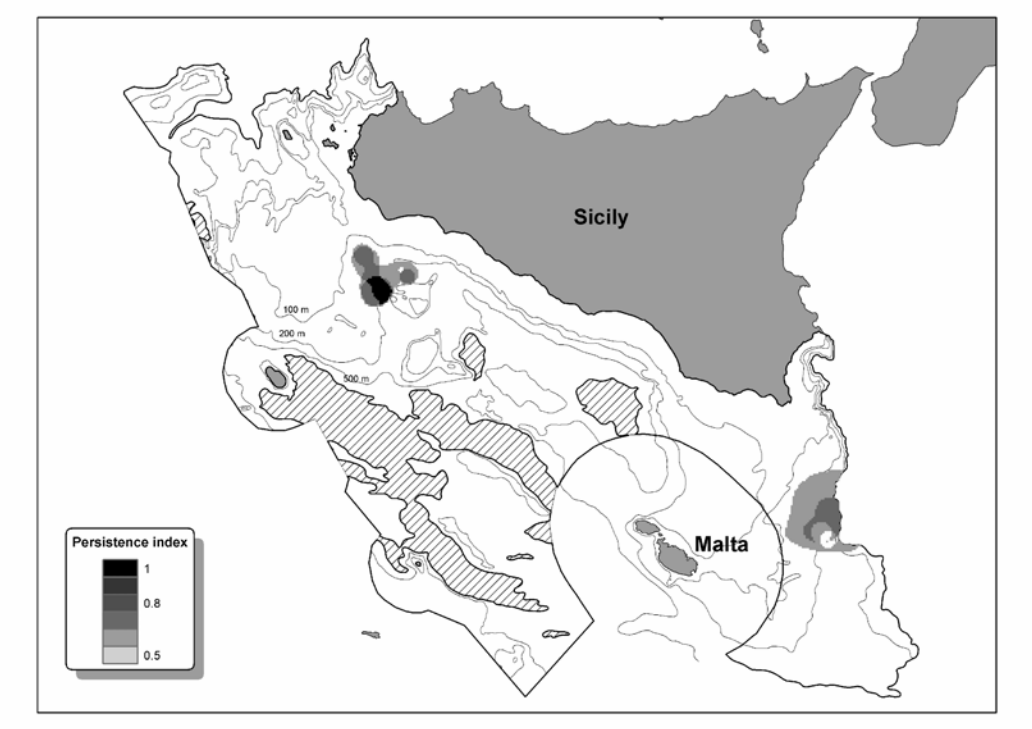


Figure 6. *Merluccius merluccius*. Stable nurseries in the Strait of Sicily (from Fiorentino *et al.* 2003a).

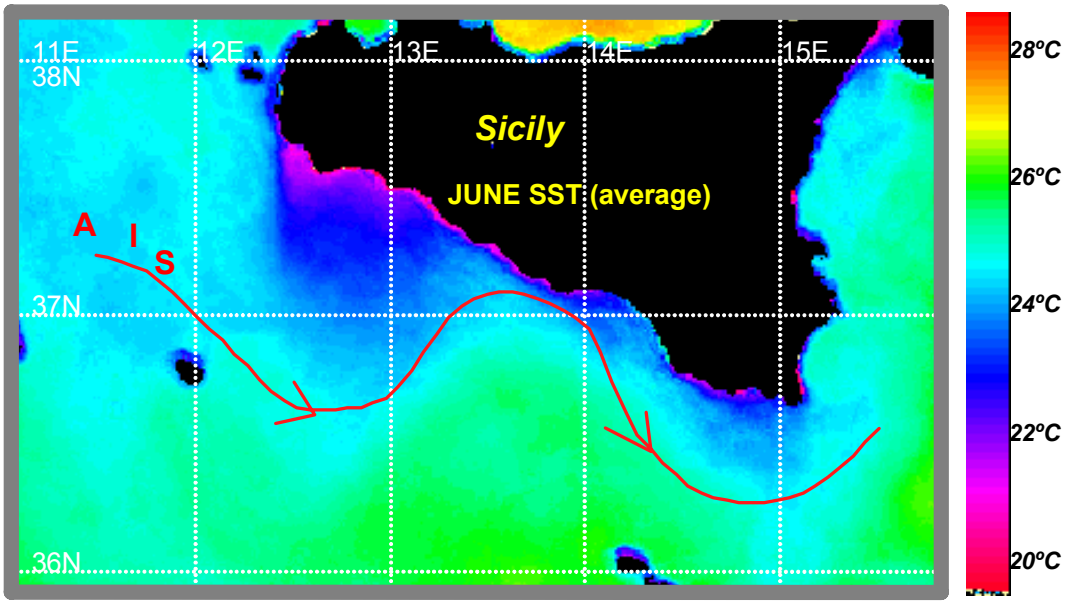


Figure 7. Sea-surface temperature and the Atlantic–Ionian stream (*AIS*) (from García La Fuente *et al.* 2002)

***Phycis blennoides*:** According to Fiorentino *et al.* (2003a), the recruits of *P. blennoides* were highly and exclusively concentrated on both the western and the eastern side of Adventure Bank, with a remarkable annual consistency. Furthermore, only in 1998 and 1999 was a high abundance of recruits found along the eastern border of the Malta bank (Figure 8).

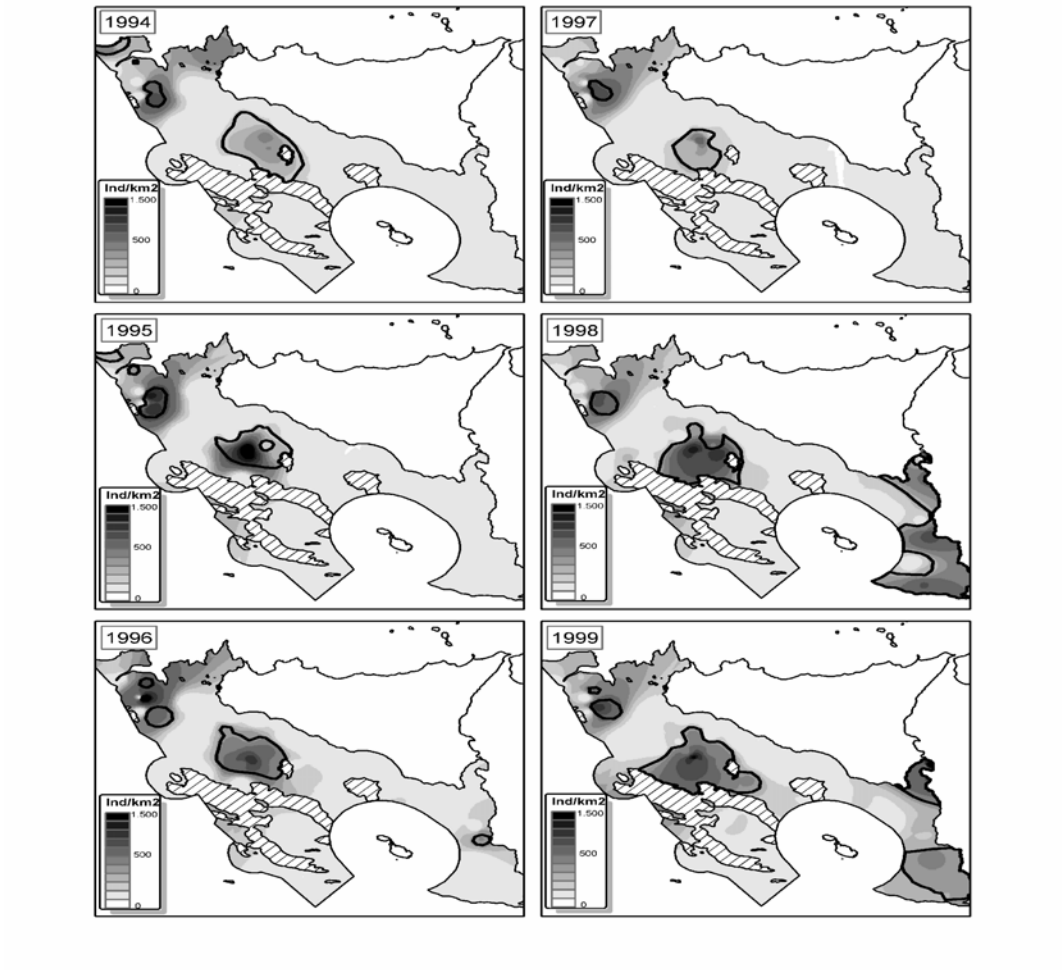


Figure 8. *Phycis blennoides.* Nurseries in the Strait of Sicily (from Fiorentino *et al.* 2003a).

The abundances of *P. blennoides* recruits were more variable than those of hake.

The analysis of the persistence of the spatial distribution of recruits throughout the period studied showed that the main nurseries of *P. blennoides* were on deeper bottoms, mainly from 200 to 400 m depth.

Regarding the 1994–1999 period, it is worth noting that the greater forkbeard recruitment was significantly correlated with that of hake, the strongest recruitment of both species occurring in 1998, whereas the lowest was in 1997.

## 3. Benthic biocenoses

The Strait of Sicily, like other Mediterranean regions, is still lacking a comprehensive classification of marine habitats and communities. Recently, Garofalo *et al.* (2002b) proposed

a first attempt to develop a large-scale thematic mapping of marine benthic biocenoses in this area, based on scientific trawl surveys (Figure 9).

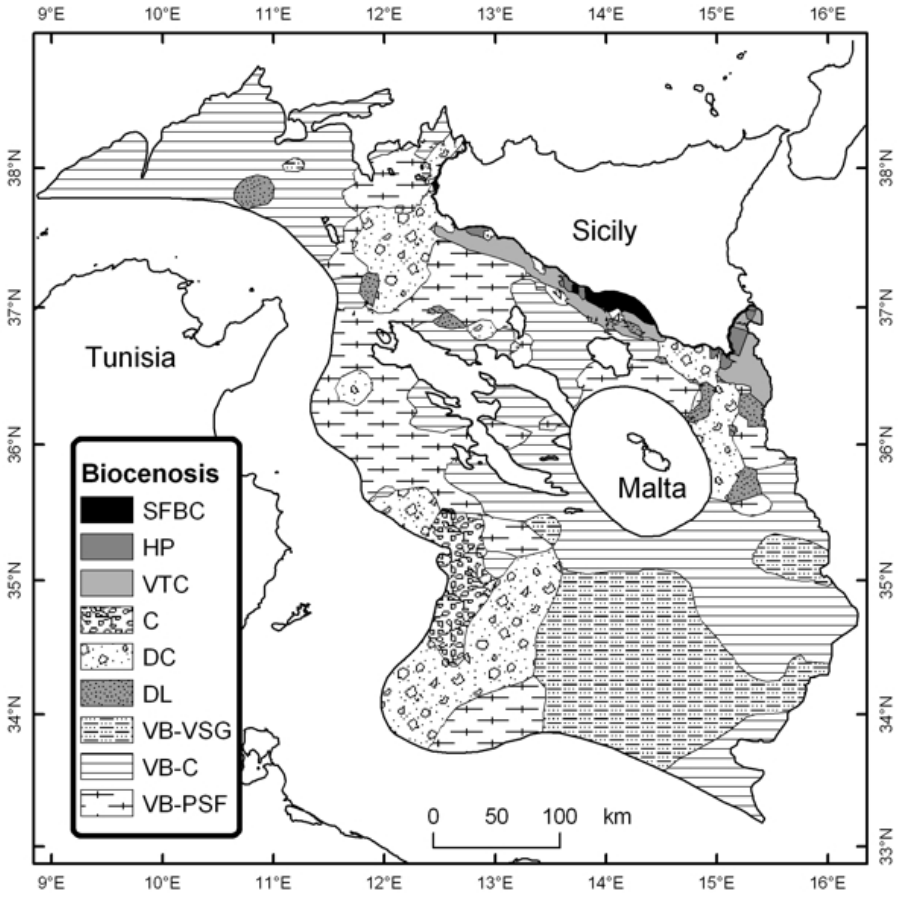


Figure 9. Map of the benthic biocoenoses in the Strait of Sicily (from Garofalo *et al.* 2002b).

From a large data set collected over a ten-year period from 1990 to 2000, hauls with presence of indicator species and substrate-type records were selected. Through the analysis of this information, with catch data, a biocenosis category, based on the Pérès–Picard (1964) classification, was assigned to each sampling site. Nine biocenosis/facies types were identified: SFBC (well-graded fine sand), HP (*Posidonia oceanica* meadows), VTC (coastal terrigenous mud), C (coralligenous), DC (coastal detritus), DL (open-sea detrital bottoms), VB-VSG (sandy muds with gravels), VB-C (compacted muds), VB-PSF (soft muds with fluid surface film).

## 4. Fishery features and spatial distribution of fishing effort

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 (Table 1). Unlike the other Sicilian fleets, about 140 large trawlers (mean GRT about 130) of the Mazara fleet,

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.

Table 1. Main features of the trawler fleet of Mazara del Vallo from 1995 to 2000, with the total gross registered tonnage and total engine power for the number of vessels specified (from Anon. 2000)

| Year | Number of vessels | Gross registered tonnage (GRT) | Engine power (kW) |
|---|---|---|---|
| 1995–1996 | 180 | 23142 | 86602 |
| 1996–1997 | 180 | 23241 | 86235 |
| 1997–1998 | 183 | 23578 | 88751 |
| 1998–1999 | 183 | 24117 | 92103 |
| 1999–2000 | 176 | 23421 | 90007 |

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). The Mazara del Vallo fleet has developed into one comprising large vessels that can operate far from the coast where the demersal resources are still economically advantageous. It should be noted that the trawlers based specifically in Mazara fish in a very large area, including parts of all the geographical sub-areas (GSs 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), 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 (A, H) with seasonal fluctuations due to the abundance of target species with high commercial value, especially *Aristaeomorpha foliacea* in spring and summer (area A) and *Mullus surmuletus* in autumn (area H) (Figure 10).

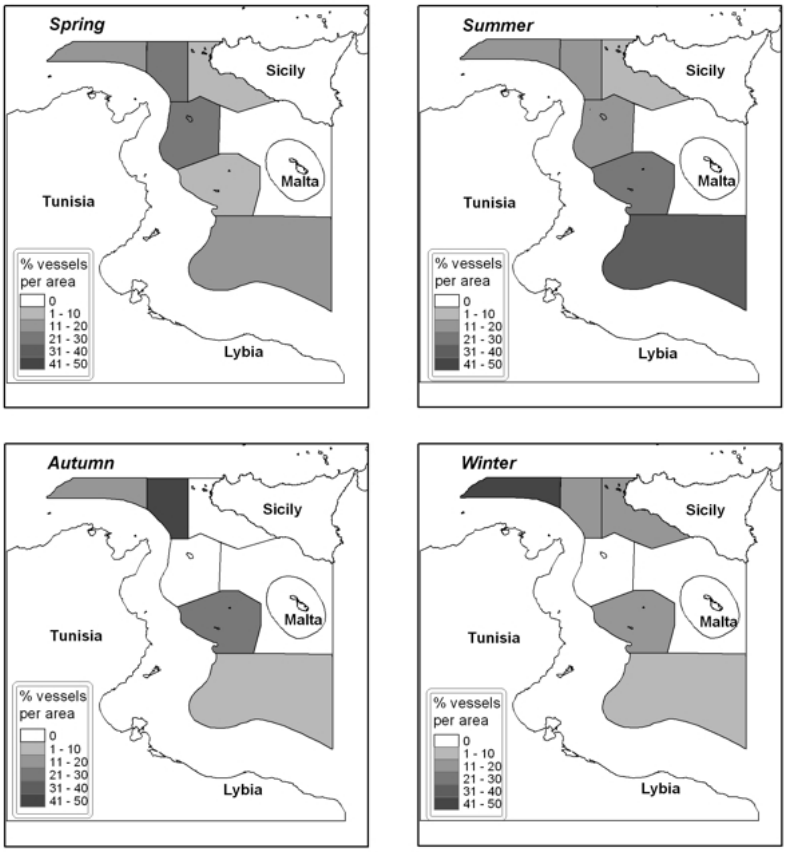


Figure 10. Seasonal distribution of the fishing pressure (unpublished data)

## 5. Effects of commercial trawl fishing in the Strait of Sicily: a spatial approach

In the last several years IRMA–CNR has attempted to contribute to the study of fishing-induced changes in composition, diversity and size spectra of demersal fish communities (Gristina *et al.* 2000; Fiorentino *et al.* 2003b; Gristina *et al.* 2003). 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 11).

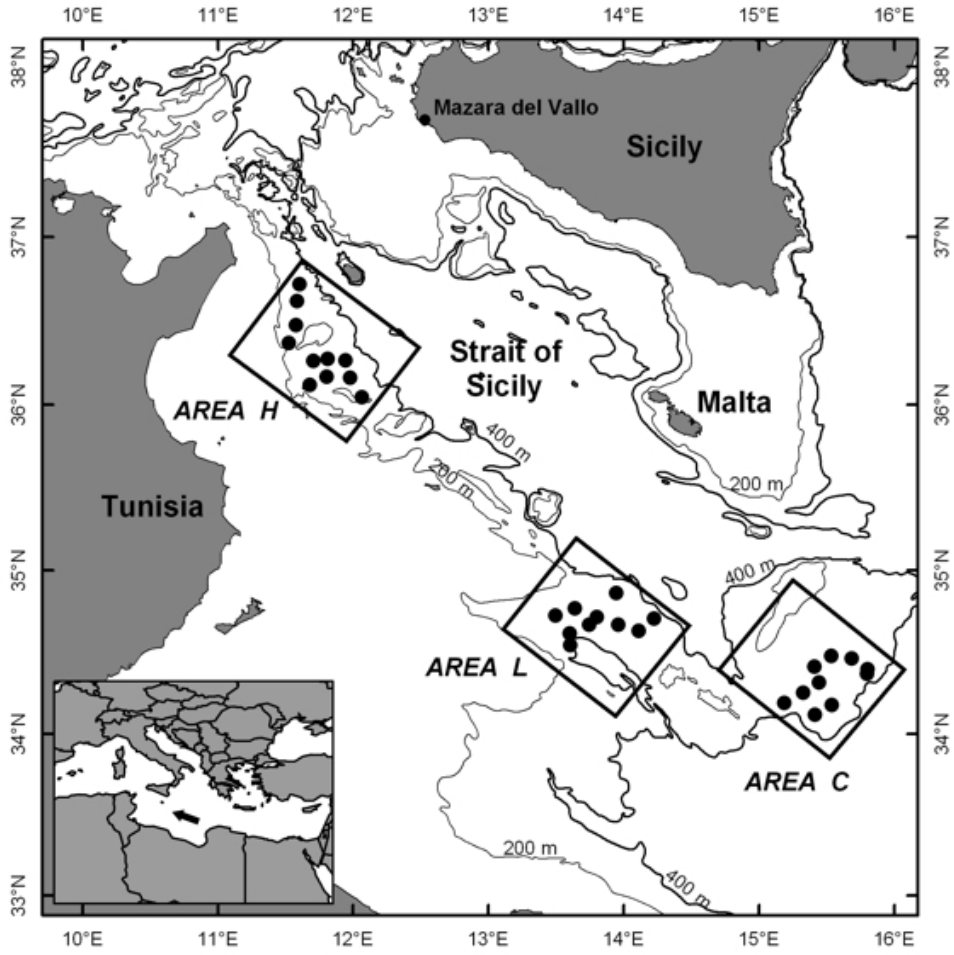


Figure 11. Areas with different level of fishing pressure (*H* high; *L* low; *C* control) (from Gristina *et al.* 2003)

In particular, we show results of biological indicator (BOI), size spectra and diversity indices (Δ and H) (Figure 12).

The analysis of the diversity index of Shannon (H) and the taxonomic distinctness index (Δ) (Hall and Greenstreet, 1998) 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.

Preliminary results on areas under different trawling pressure in two specific years (1997 and 1998) suggested that the ratio between biomass of "bottom-dwelling fish" and that of "all fish" (BOI) could be useful in measuring trawling impact on the demersal fish assemblages.

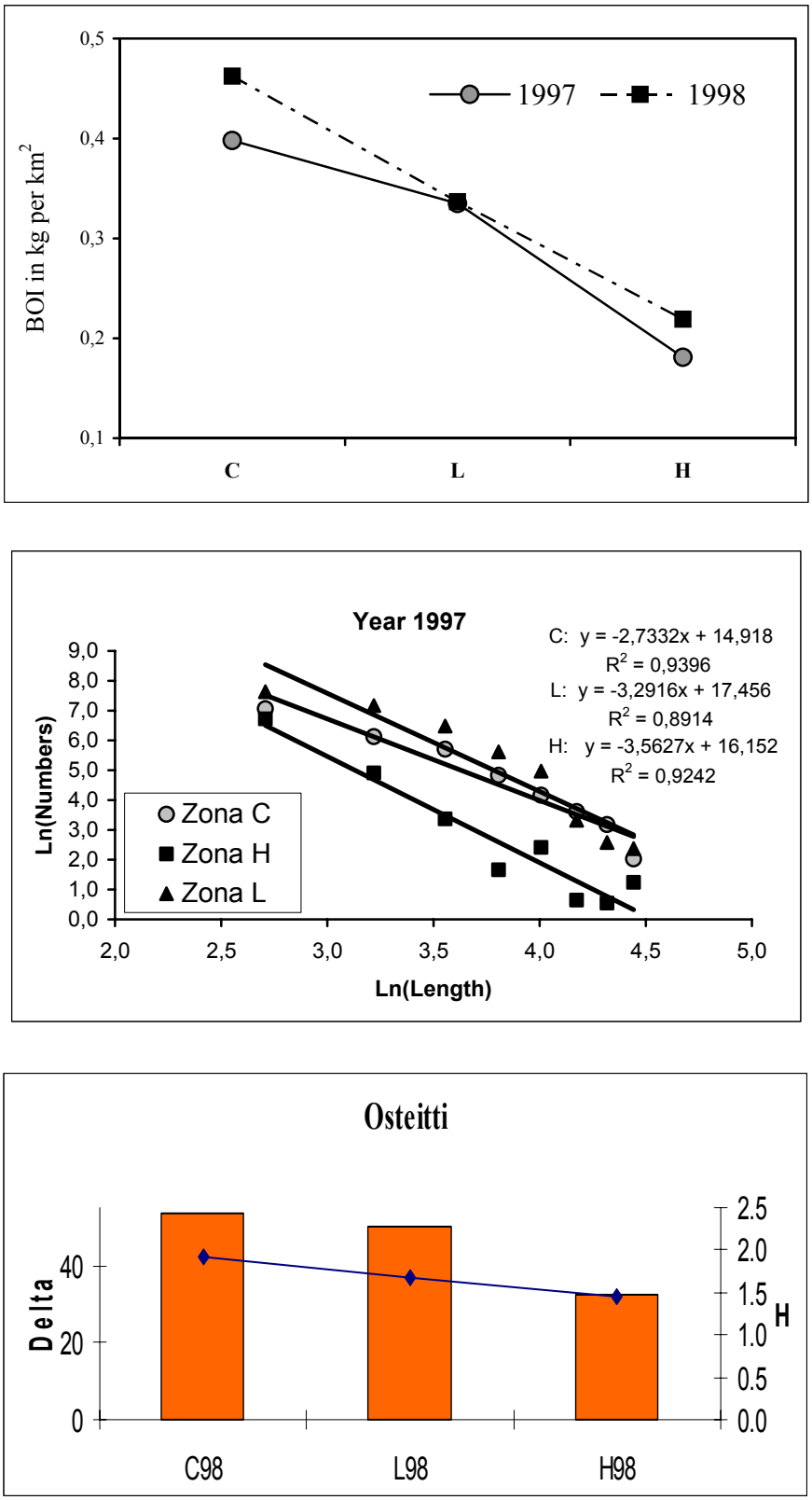


Figure 12. Multispecific indices from areas with different level of fishing pressure (H high; L low; C control) (from Fiorentino *et al.* 2003b; Gristina *et al.* 2000, 2003)

## 6. Discussion and conclusions

Evidence has been accumulated in recent years showing that the spatial distribution of species' populations represents a useful tool for the identification of stocks and helps in giving advice on short-term management problems (Pawson and Jennings 1996). According to these authors, the information above should be used in a more robust management framework, integrating analyses of the spatial distribution of the fishing pressure and of the main environmental features (sedimentological, hydrographical and benthic aspects) which affect the stock dynamics.

In particular, three main points need to be developed:

- An increasing number of studies indicate that the abiotic and the biotic components of the sea bed are of great importance in determining the distribution of the main critical phases (spawning, nursery and feeding areas) of the majority of biological resources (Stoner and Abookire 2002). Further ad hoc sampling surveys are necessary in order to improve the classification of biocenoses on hard substrata and in the infralittoral zone. Sedimentological maps of the soft bottom in the Strait will also be useful.
- Evidence has shown that hydrographical features can strongly affect structure, composition and abundance of the biological resources in the Strait of Sicily (Jereb *et al.* 2001; García La Fuente *et al.* 2002; Levi *et al.* 2003a). Additional studies are necessary to fully investigate the coupling of the environmental factors and the life stages of the main demersal species in the area.
- Trawl fishing has a strong direct impact on the population of the target species and on the benthic communities. Moreover, effects on non-target species and on marine ecosystems as a whole have also been demonstrated. More detailed knowledge of the spatial distribution of the trawl fleet operating in the Strait of Sicily is fundamental to the development of management options. The spatial distribution of the trawl fleet appears to be strictly linked to the market demand and to the fluctuation of the market price of specific life stages (juvenile) of the main target species.

The possibility of describing the co-variation of descriptive parameters on large space- and time-scale represents an important complement to the still prevalent "reductionist" approach to stock assessment. The MedSudMed programme should be dedicated to understanding how fish stocks react to environmental and fishing impacts, with the long-term aim to translate this information into a useful socio-economic format. Within this framework, GIS applications, which integrate several types of information (resource-abundance data, fish assemblages, biocoenoses, substratum type, hydrographical features), enable one to study cause-and-effect relationships which serve as preliminary but necessary knowledge for the sustainable exploitation of shared marine resources in the Strait of Sicily.

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