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THE IMPACT OF TRAWL FISHING ON THE SEA BOTTOMS: CHOOSING AN EXPERIMENTAL AREA

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RIASSUNTO

L'impatto della pesca a strascico sui fondali marini: scelta di un'area sperimentale.

A partire dagli anni venti anche i pescatori inglesi hanno attirato l'attenzione sulle possibili alterazioni a carico dell'ambiente marino causate dall'attività di pesca. Ciononostante, a distanza di ottant'anni la letteratura scientifica annovera un limitato numero di lavori realizzati con lo scopo di valutare gli effetti della pesca a strascico sui fondali deI Mediterraneo. Recentemente, la Comunità Europea ha sovvenzionato uno studio mirato alla valutazione dell'impatto indotto sperimentalmente attraverso una serie di strascicate ripetute nell'arco delle ventiquattro ore in due aree del Mediterraneo occidentale, rispettivamente al largo della costa italiana e spagnola.

Il progetto, ancora in corso, è stato articolato in tre fasi: ricerca e caratterizzazione dell'area di studio, campagna sperimentale di disturbo e valutazione dell'impatto a breve termine (immediatamente dopo, 24 e 48 ore dopo), valutazione dell'impatto a medio termine (uno e sei mesi dopo).

L'indagine è stata condotta utilizzando side scan sonar, ecoscandaglio di precisione e video camera subacquea per investigare la morfologia del fondale e per rilevare eventuali tracce lasciate dalla pesca illegale. Box corer e benna Van Veen sono stati usati per prelevare i campioni di sedimento per lo studio delle caratteristiche fisiche (granulometria) e bionomiche dell'arca.

Lo studio ha consentito di individuare un'area tra i 25 e i 35 m omogenea da un punto di vista bionomico e fisico. In quest'area la pesca illegale appare limitata, condizione importante per poter monitorare nel tempo gli effetti conseguenti al disturbo indotto sperimentalmente.

La medesima area è stata scelta anche perché, essendo caratterizzata da condizioni di basso idrodinamismo, conserva più a lungo i segni lasciati dalla rete a strascico.

In questo lavoro si riportano inoltre, seppure in forma preliminare, alcuni risultati relativi ai tasks 3 e 4 con alcuni commenti e suggerimenti.

ABSTRACT

Recently, an increasing interest has been focused on the impact of commercial fishing on the sea floor habitats but, till now, very little information regarding the Mediterranean Sea is available.

The aim of the present project funded by European Commission *("Environmental impact of trawling on benthic system on two different sea beds of the NW Mediterranean Sea"* study proposal n° 97/0020) was to investigate the impact of repeated experimental trawl disturbance induced by an otter bottom trawler, in two areas of the Mediterranean Sea (off the Italian and Spanish coast) characterised by different substrata.

In order to fulfil the objectives of the project 3 tasks were planned: identification and characterisation of the experimental area; experimental disturbance cruise and short-term - *i.e.* immediately after, 24 and 48 hours after disturbance - effects detection; medium-term - *i.e. 1* and 6 months after disturbance - effects.

The project is actually onward and the reprocessing data activities are not yet complete.

In this paper some results of the first cruise, carried out for identifying the experimental area, are reported. The survey was carried out by using different methods to obtain different levels of information. Side scan sonar, echo sounder, and underwater video camera were used to investigate the bottom morphology and check for likely previous trawling activities. Box corer and Van Veen grab were adopted to collect sediment samples in order to investigate benthic community and carry out grain size analysis.

The investigation allowed choosing an area between 25 and 35 m of depth which resulted homogeneous from the biological and textural point of view. This area itself resulted poorly affected by commercial fishing and characterised by low hydrodynamic condition allowing a better monitoring of the experimental induced effects.

In addition methods and preliminary results of the task 2 and 3 are reported with some parallel comments and suggestions.

Key-words: fishery disturbance, benthos, grain size, (MDS), NW Mediterranean.

THE PROBLEM AND RECALL TO THE PROJECT'S OBJECTIVES

The impact of commercial fishing on the sea floor habitats has been focused since twenties by English fishermen (Anon., 1921), but complaints about the possible environmental effects of the use of trawls date back to the thirteenth century (de Groot, 1984).

Nevertheless, many studies on the impact carried out in the North Sea (sea Kingston & Rachor, 1982 for a review) under-estimated, for many years, the role of fishing. The observed modifications in macrozoobenthic communities were, in fact, mostly attributed to human impact or eutrophication (Rachor, 1990).

The strongly increasing fishing activity forced, in the sixties, the International Council for the Exploration of the Sea (ICES) to request investigations on the effects of trawls and dredges on the sea bed and the benthic fauna (Anon., 1988). These studies remained isolated for more than ten years when a group of ICES components (researchers, members), by re-examining the impact of bottom trawling proved there were strong effects on benthic communities and focused on the need for further investigations.

Since then, great scientific interests arouse and in several countries many studies regarding physical and biological impact by fishing gears were carried out.

Despite many investigation have been carried out, a general pattern for the impact has not been described yet because of the high number of variables to check simultaneously.

In addition, nowadays marine environment is subject to a severe anthropogenic impact, which induces changes in natural fluctuations, so that discrimination between them and fishery-generated changes is still quite unclear.

Furthermore, published results arc related to studies carried out in the North Sea, Irish Sea, Australia, America, while very little information exists about the Mediterranean Sea (Simboura *et al.,* 1998; Smith *et al.,* 1997; Pranovi *et al.,* 1998; Giovanardi *et al.,* 1998).

The aim of the project was to investigate the impact of repeated experimental trawl disturbance induced by an otter bottom trawling, in two areas of the Mediterranean Sea (off the Italian and Spanish coast) characterised by different substrata.

In particular the following general objectives were planned:

- to check alterations on the sea bed morphology;
- to check alterations on the texture of the sediments;
- to monitor sediments removed;
- to investigate changes in macrobenthic infauna;
- to analyse the experimental trawl catches.

In order to fulfil the aims of the project 3 tasks were planned: identification and characterisation of the experimental area; experimental disturbance cruise and shortterm - *i.e.* immediately after, 24 and 48 hours after disturbance - effects detection; medium-term - *i.e.* 1 and 6 months after disturbance - effects detection.

The project is presently onward and the activities related to data processing have not come to an end yet, so in this paper only some results of the first cruise, carried out in order to identify an experimental area off the Tuscany coast (Italy), are reported. The aim of the first cruise was to select a homogeneous area - from a biocoenosis point of view - characterised by muddy or muddy-sandy sediments. In addition the area should have been unaffected by previous fishing activities to allow a separation of the experimentally induced effects from the changes related to commercial fishing.

In addition methods and preliminary results of the tasks 2 and 3 are reported with some parallel comments and suggestions.

METHODS

Task I

The characterisation cruise was carried out from 26th June to 1st August 1998 off the Tuscany coast in the North Tyrrhenian Sea (Fig. 1) to select a marine area suitable for the experimental trawl disturbance.

The survey was carried out by using different methods to obtain different level of information. Side scan sonar, echo sounder, and underwater video camera were used to investigate the bottom morphology and check for likely previous trawling activities. Box corer and Van Veen grab were adopted to collect sediment samples for investigating on benthic community and performing grain size analysis.

Bottom morphology

A marine area between 8 and 35 m of depth, approximately 2.7 km x 5.5 km wide, was investigated by side scan sonar. It was towed along fifteen way-lines, ca 5.5 kin long, from south to north at a speed of 1,8 - 2 m s^{-1} at varying height above the sea bed according to the water depth.

The range of side scan sonar was set at 100 m on either side of the centre of the instrument. The distance between two parallel tracks was 160 m. The emission frequency varied between 185-225 kHz.

Bottom investigation was also performed through an underwater towed vehicle provided with a video-camera connected by a cable to a boat, where the images of the bottom were observed and recorded.

The vehicle was located at a distance of I-10 m on the bottom with a shot range of 1.515 m. Boat, cable and telecamera can be considered as a system unit, so that the coordinates of recorded images can be compared to those detected by GPS on the boat if a short delay is taken into account.

Bottom images were recorded along 3 transects orthogonal or diagonal to the coast starting about at 17 m of depth down to 35 m of depth. Observations from shallow to deep bottoms allow the best interpolation of discontinuous images of benthic communities distributed according to the depth gradient (Somaschini *et al.*, 1998).

Start and end coordinates of each transect follow:

1 - start	43.05.298 N 10.31.360 E	depth: -18m
end	43.05.286 N 10.30.11 E	depth: -35m
2 - start	43.04.794 N 10.31.396 E	depth: -16m
end	43.04.331 N 10.30.167 E	depth: -32m
3 - start	43.04.272 N 10.31.336 E	depth: -17m
end	43.04 259 N 10.30.039 E	depth: -34m

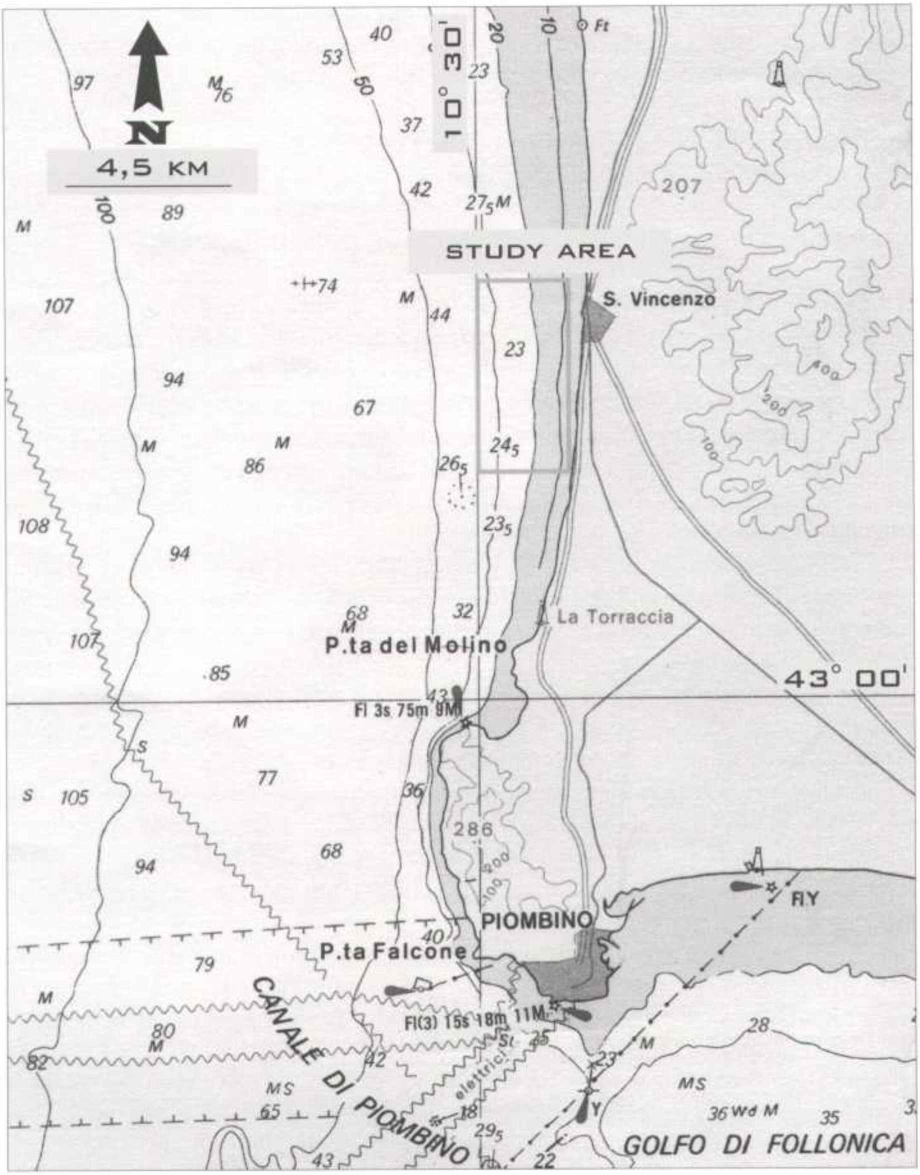

Fig. 1: Study area.

Fig. 1: Area di studio.

The bathymetry survey was carried out by an echo sounder, along the same tracks of a side scan sonar. In addition 7 tracks from east to west, approximately 2.8 km long, were surveyed. The distance between two lines was 500-1000 m.

Sediment analysis and benthic communities

Sediments were collected in sixteen stations fixed along 4 transects parallel to the coast between 15 and 35 m of depth. Sediment samples were analysed for their particle size according to the Udden-Wentworth Phi classification. Each sample, after washing in 16% hydrogen peroxide for 24 hours, was sieved wet on a 63-pm-mesh sieve to sort out the fine fraction. The sand fraction was sieved through a stack of geological testsieves ranging from 0 Phi to +4 Phi. The fine fraction was then analysed by sedigraph.

For each sample the index of coarseness or sand equivalent was calculated according to Satsmadjis (1982). The hydrodynamic conditions of the area were estimated by computing, for each sample, the skewness parameter according to Folk & Ward (1957).

Non-metric Multidimensional scaling (nMDS) ordination was also performed for the environmental data (grain size, latitude, depth, skewness). Dissimilarity was calculated as normalised euclidean distance.

For benthic community analysis samples were collected in the same stations mentioned above, in order to investigate macrozoobentic community and calculate the minimum sampling area. Three-five replicate samples were collected, where possible, with a 0.5-square-meter-box-corer.

The shallower stations (I A, I B, 2A, 2B), characterised by sandy sediments, of both the first and the second transect were collected by a Van Veen grab because box corer resulted unsuitable for collecting sandy sediments.

The stations at 15 and 20 m of depth along the third and fourth transect (3A, 3B, 4A, 4B) were not sampled because of the presence of *Posidonia oceanica* meadows.

Sediments were sieved through Imm mesh sieve and then fixed in 10% buffered formalin. Samples were sorted in laboratory, macrofauna species were identified to the lowest possible taxonomical level.

Cluster analysis and Multidimensional Scaling ordination (Kruskal & Wish, 1978) were performed on a Bray-Curtis similarity matrix after log (x+1) transformation of the species abundance data. Both classification and ordination were based on the mean abundance of species for each station.

Circles with a diameter proportional to the value of coarseness were superimposed to MDS ordination plot obtained through the biological data to investigate the role of the grain size on the distribution of the benthic community.

nMds was re-run by merging environmental parameters (grain size, latitude, depth, skewness) and biotic data (dominance of higher taxa, structural parameters). Dissimilarity was calculated as a normalised euclidean distance.

The Bio-Env procedure (Clarke & Warwick, 1994) was used to select a subset of variable maximising rank correlation (p) between biotic and mixed - abiotic *plus* biotic data - (dis)similarity matrices.

Task 2 and Task 3

During the experimental cruise fishing disturbance was induced by 15 repeated hauls lasting about one hour, utilising a medium sized commercial trawling vessel with a wide vertical opening trawl net (warps: principal of 12 mm of diameter, secondary of 8 mm of diameter and 16 m length).

In order to investigate the trawling effect on sediments and benthic communities the basic Before/After, Control/Impact (or BACI) design has been adopted. This method involves multiple control and treatment sites before and after the experimental cruise, to avoid problems of spatial confounding (pseudoreplication).

Before and after (immediately after, 24, 48 hours after) the experimental cruise side scan sonar and video camera surveys were carried out. Samples for sediment and benthic community analyses were collected in 10 stations: 5 inside the impacted area and 5 (controls) outside.

In addition CTD profile was repeated before and after trawling to record clouds of suspended sediment produced by trawling. Measures were collected according to two different strategies: repeated samples in the same station for one hour - to investigate the destiny of clouds over time i.e. temporal gradient - and samples along a transect at increasing distance from the impacted area - i.e. spatial gradient. Benthos was not investigated immediately after disturbance because, according to Currie & Parry (1996), the maximum impact does not occur immediately after trawling impact. In order to fulfil the objectives of the task 3 the same protocol was adopted I month and 6 months later.

RESULTS

Task I

Bottom morphology

The area was characterised by the presence of *Posidonia oceanica* meadow, which colonises the marine bottom from a few meters down to 20-22 m of depth. This meadow represents only a small portion of a wider prairie extending, with some interruptions, along the Tuscany coast. Its density and cover displayed a high variability and patchiness indicating a stressed situation.

The meadow showed lower limits and patterns in the body of the prairie itself suggesting that different type of erosion and hydrodynamic conditions occurred despite the limited extension of the area investigated.

In the northern sector, the prairie resulted narrow (lower limit between 11 and 15 m of depth) and grows on "matte" (French term used to indicate the sea floor elevation produced by the aggregation of roots and rhizomes persisting after the death of the leaves). It was generally dense and ends sharply on sandy bottom, sometimes with a decrease in plant density.

In the central sector *Posidonia* bed extended from 7-8 to 12 m of depth and was bordered by patches of leave and dead matte which ended irregularly between 18 and 20 m of depth.

In the southern sector a different and more heterogeneous situation took place. *Posidonia* on matte, dead matte and spotted plants occurred together. In addition isolated patches growing on rocky substrata surrounded by sandy soft bottoms were also present, thus increasing the local complexity.

By comparing previous maps (Bianchi *et al.*, 1995) the meadow appears wider than expected. Probably it is a consequence of the large cartographic scale adopted in advance rather than inaccuracy in surveying and mapping methods.

The side scan sonar survey allowed to record that the marine bottom is affected by commercial fishing mostly over 34 m of depth (Fig. 2).

Sediment analysis and benthic communities

The percentage of sand, silt and clay of each station are shown in fig. 3. The sediments varied considerably in texture, consisting from 2.9 to 77.8% sand according to depth gradient: from shallow to deep stations sand is gradually substituted by finer sediments.

This gradient is well stressed by the coarseness index (s'): it reaches its maximum value at stations IA (s'=78.4) and 2A (s'=73.2) close to the coast and its minimum in station 4E (s'=14.7) situated in southern and deeper sector of the study area (Fig. 4).

All the area is characterised by low and highly hydrodynamic conditions according to skewness parameter, which varies from 0.11 to 0.65 (fig. 4).

In fig. 5 results of cluster analysis and nMDS ordination plot from environmental data are reported. Stations were clearly grouped according to their spatial distribution along the bathymetry gradient.

A total of 1716 infaunal invertebrates belonging to 132 species or major taxa were collected. The list included polychaetes, crustaceans, molluscs (16%), echinoderms, sipunculans, cnidarians, pycnogonida, and bryozoans.

Fig. 6a is a dendrogram showing affinities between stations based on the log (x+1)-transformed abundance of all species, using the Bray-Curtis measure of similarity and group average fusion strategy.

A broken line drawn at the similarity level of 45% delineates 4 major groups and two outliers.

Group 1 comprises the shallowest stations at 15 m of depth; group 2 the two stations at 20 m of depth; group 3 stations between 25 and 35 m of depth belonging to the first, the second and the third transect (except for station 3C). The last group includes the stations at 25 and 30 m of depth in the fourth transect.

The fig. 6b shows the results of multidimensional scaling using the same similarity matrix as above, delineating groups of stations from the dendrogram. The value of stress for the 2-D plot is very low indicating an excellent representation of the relationship between the stations.

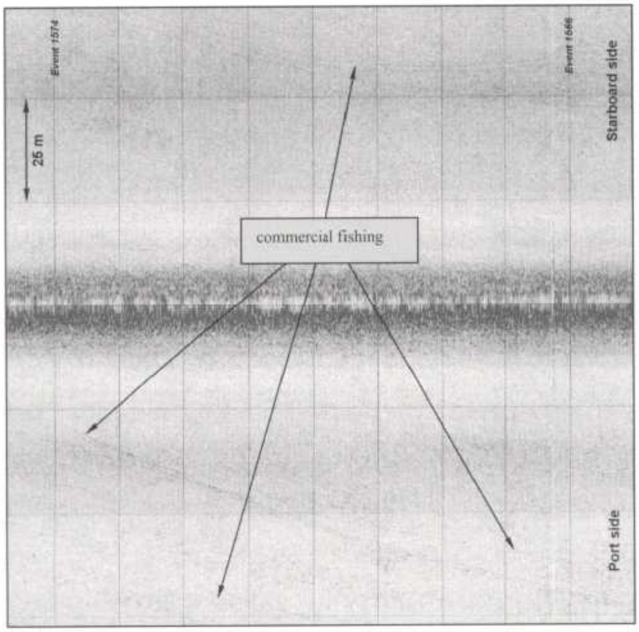

Fig. 2: Side scan sonar record showing that the area is affected by commercial fishing.
Fig. 2: Registrazione di una immagine side scan sonar che rivela un'area interessata dalla pesca commerciale.

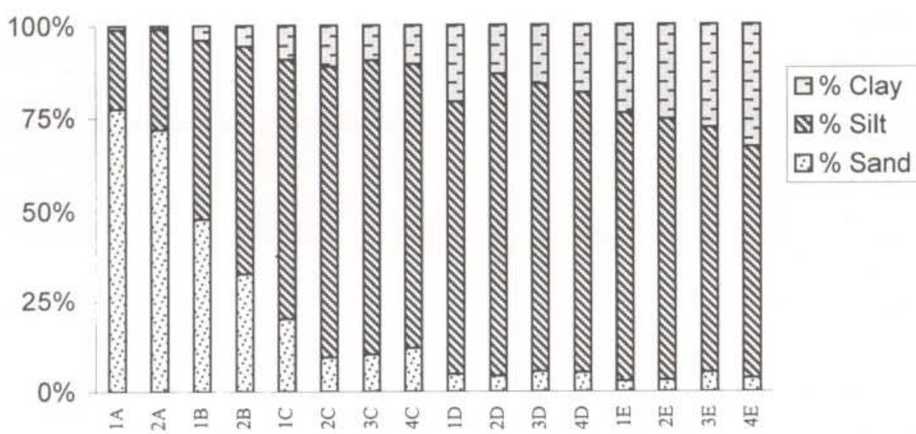

Fig. 3: Percentage of sand, silt and clay for each sampling station.
Fig. 3: Percentuale di sabbia, silt e argilla per ciascuna stazione di campionamento.

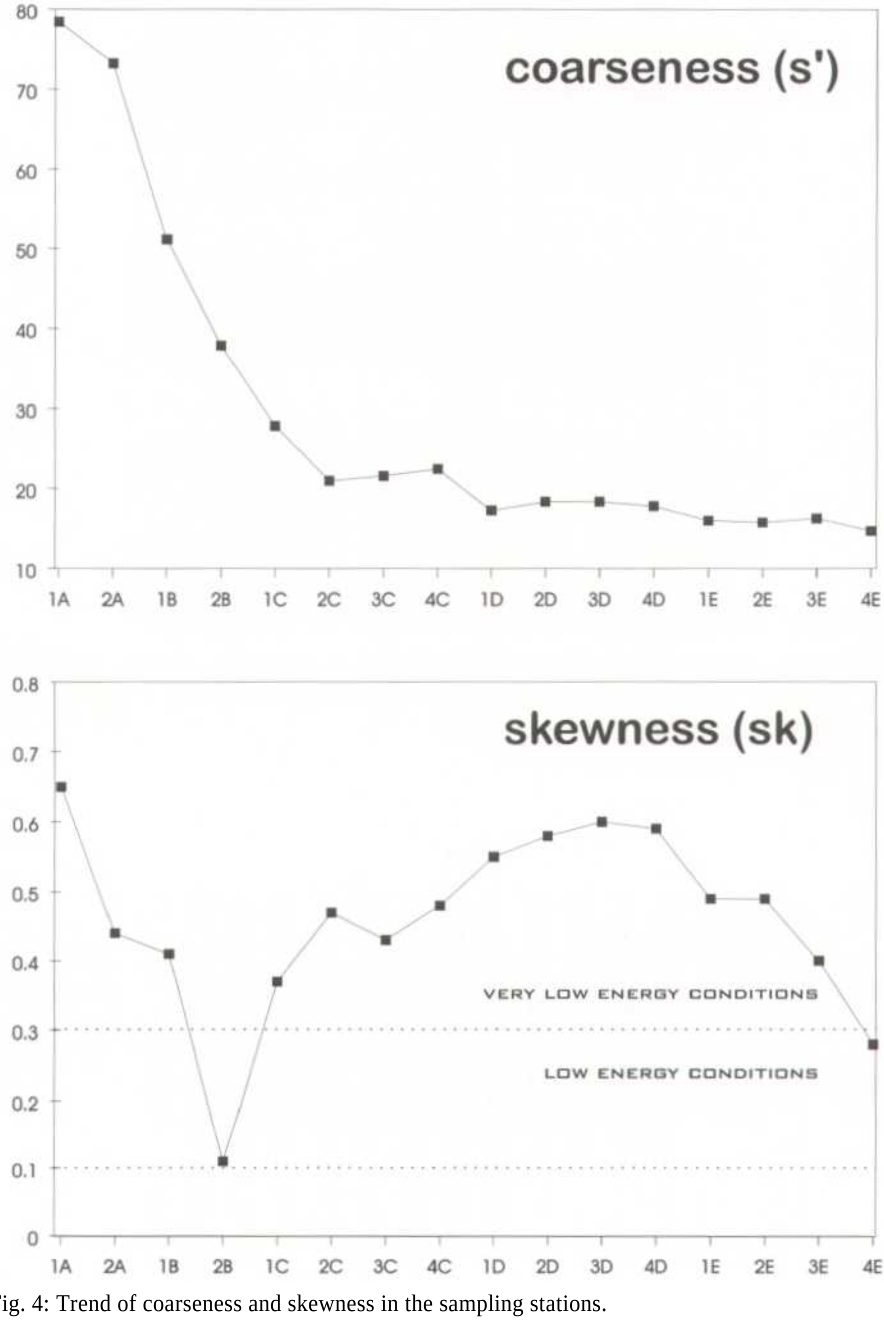

Fig. 4: Trend of coarseness and skewness in the sampling stations.

Fig. 4: Andamento della presenza di sedimento grossolano e cui-va di asimmetria nelle stazioni di campionamento.

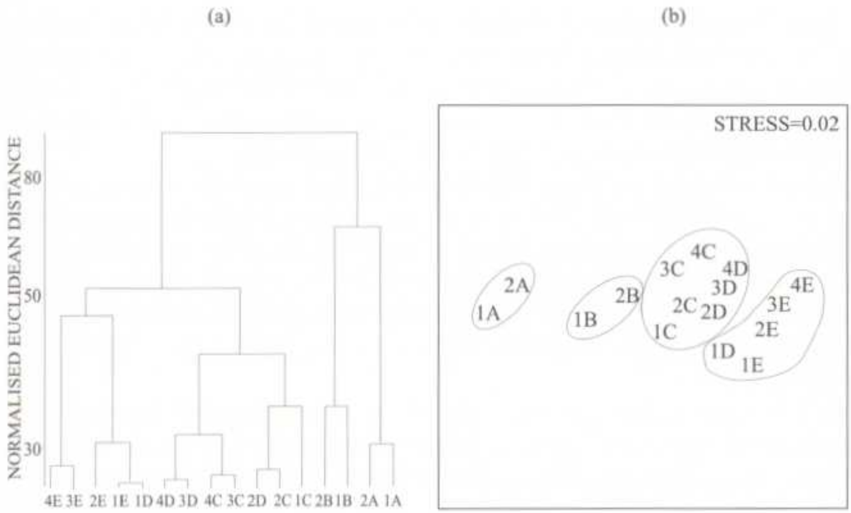

Fig. 5: Cluster analysis (a) and nMDS plot (b) from environmental data.
Fig. 5: Analisi dei cluster (a) e diagramma di raggruppamento di tipo nMDS (b) utilizzando dati ambientali.

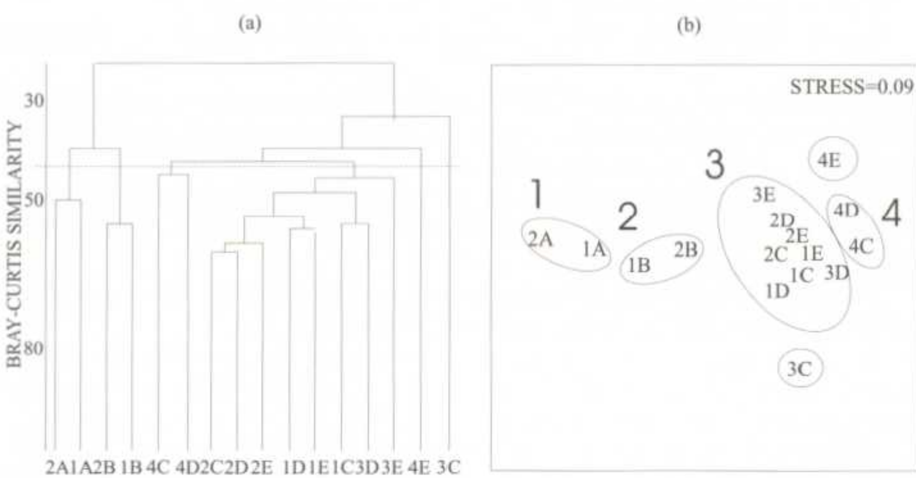

Fig. 6: Cluster analysis (a) and nMDS ordination plot (b) from abundance matrix.
Fig. 6: Analisi dei cluster (a) e diagramma di raggruppamento di tipo nMDS (h) utilizzando una matrice di abbondanza.

They are distributed in the ordination plot according to their increasing distance from the coast reflecting their topographic location. Clusters reflected only partly the bathymetry gradient: it is clear for shallow stations - stations at 15 and 20 m of depth were well discriminated from each other and from deeper stations -, but stations at 25, 30 and 35 m cluster all together despite their different depth.

A different situation occurs along the third transect close to the *Posidonia oceanica* meadow: stations at 25 and 30 m of depth were separated from the deepest station.

Shallow stations were characterised by species living in the sand, such as *Spisula subtruncata, Nassarius mutabilis, Owenia fusiformis, Dosinia lupinus,* considered `exclusive feature' of Picard's SFBC (Biocenose des Sables Fins Bien Calibrés, Picard, 1965), a community which typically colonises well-sorted sandy sediments close to the coast.

At increasing depth community gradually merges species with muddy sediments affinity such as *Sternaspis scutata, Labidoplax digitata, Turritella comm unis, Mysella bidentata.* This community can be referred to the VTC biotic (Vase Terrigène Côtièr, Picard, 1965).

In fig. 7a MDS ordination plot from the mixed matrix (environmental parameters *plus* biotic data) is shown. Groups were based on the results of the cluster analysis of the fig. 7b.

The bathymetry gradient is most pronounced for stations belonging to the first and the second transect. Stations of the fourth transect and partly of the third one were not included in the same cluster despite their similar depth range.

From the Bio-Env procedure the best variable combination (p=0,629) involves coarseness, latitude, richness.

Fig. 8 represents a schematic drawing of results obtained by nMDS.

The distribution of the benthic communities is likely to depend on at least two factors.

First of all the study reveals that the zonation of the benthos is primarily under the influence of the grain size which, in turn, is strongly related to the bathymetry gradient. It is widely accepted that the roughness of the sediment is a relevant ecological factor affecting structure and functioning of the littoral non-vegetated benthic communities.

The second factor is not clearly identifiable, its influence has been revealed in the southern portion of the studied area.

Clustering and ordering of the stations of the southern part of the area resulted different than expected by comparing their depth and grain size.

It is likely that *Posidonia oceanica,* which colonises deeper substrata than the northern sector of the meadow, increases the local heterogeneity that, in turn, induces increasing complexity and variability on the surrounding benthic communities.

Such an influence is not very strong, but strong enough to modify both faunistic - as supported by the results of cluster and MDS on the abundance matrix- and structural feature - as supported by the results of cluster and MDS on the mixed matrix - so that the community of this area can be considered as a cenotic assembling by itself.

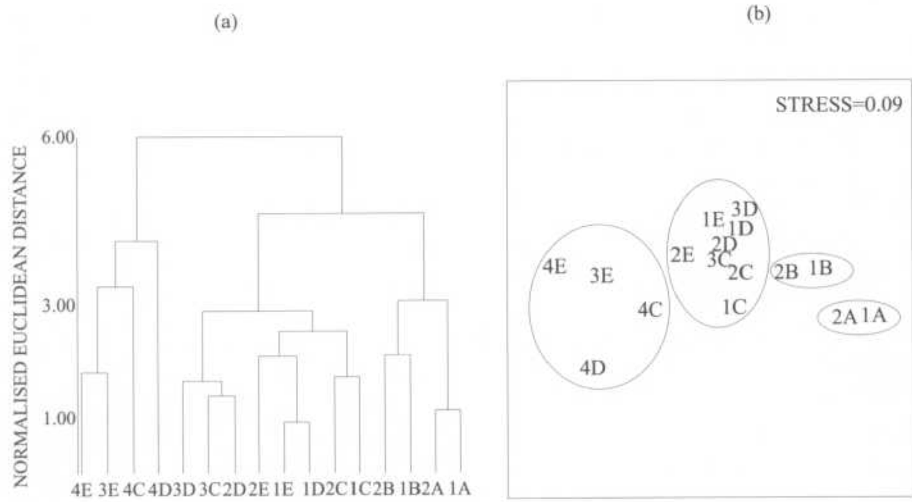

Fig. 7: Cluster analysis (a) and nMDS ordination plot (b) from the mixed matrix.
Fig. 7: Analisi dei cluster (a) e diagramma di raggruppamento di tipo nMDS (b) utilizzando una matrice mista.

That pattern leads to consider this area unsuitable to investigate experimental trawling effects.

The experimental trawling will be carried out between 25 and 35 m of depth where the area resulted homogeneous from the biological and textural point of view.

The area itself resulted poorly affected by commercial fishing, thus allowing an easier discrimination between experimental and commercial fishing-induced effects.

Furthermore it is characterised by low hydrodynamic condition allowing, according to some other authors (Thiel & Schriever, 1990), a better monitoring of the experimentally induced effects.

Task 2 and Task 3

- Alteration of the morphology of the sea bottom can be clearly detected: trawl tracks arc still evident after 6 months.
- Significant changes in the sediment texture can be detected only immediately after trawling: in the impacted area a decrease in the amount of clay was observed.
- Strong changes at community level were not detected. Further re-elaboration of the data set will allow a more detailed investigation at species level. Presently only a small increase in opportunistic short-lived species has been observed.
- Alteration of the water column turbidity was detected only for half an hour.

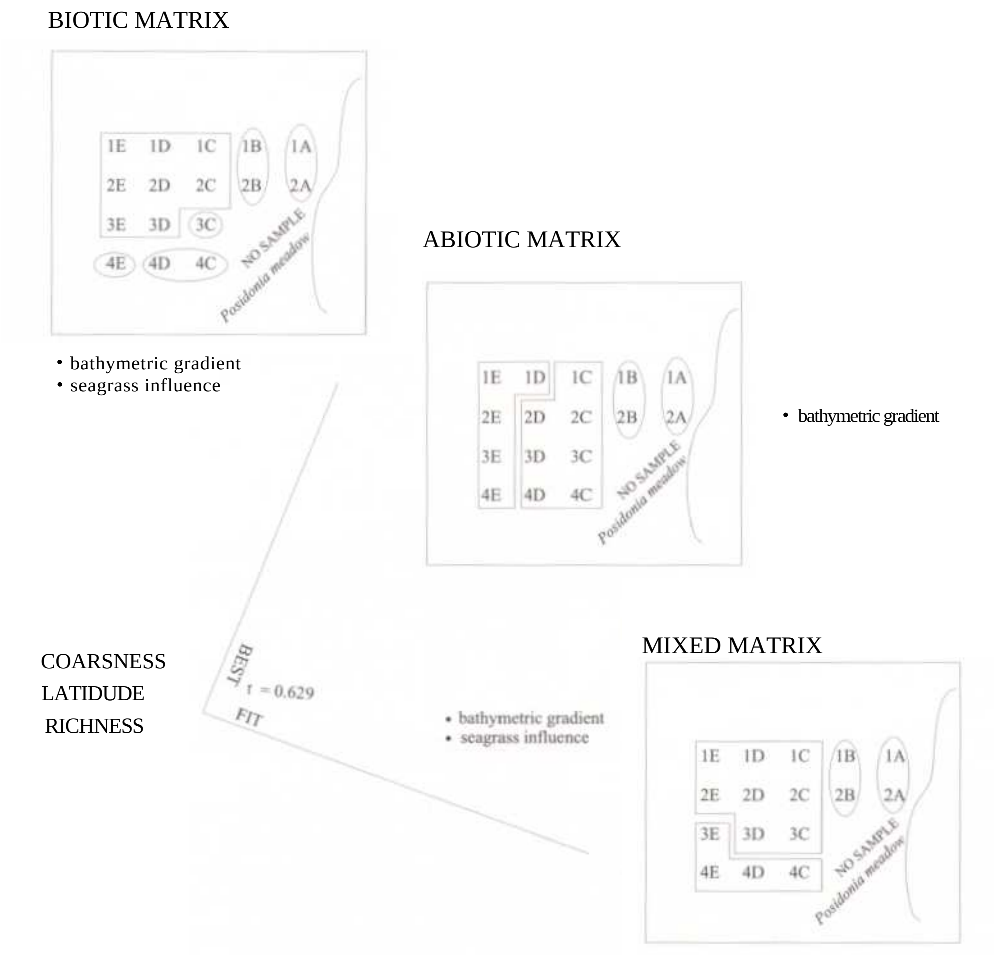

Fig. 8: Schematic drawing of multivariate analysis results.

Fig. 8: Schema dei risultati dell'analisi multivariata.

COMMENTS

Infauna seems a less suitable indicator than epifauna in detecting trawl-induced changes.

Even our studied area resulted affected by illegal commercial fishing. So it is likely that community is resistant to further disturbance. Local disturbance could be considered as trivial if compared to that previously caused.

Most of the studies regard the disturbance of such small experimental areas so that it is a difficult task to extrapolate the results to the scale of commercial fishery.

SUGGESTIONS

In order to carry out studies in large areas closed to fisheries for many years, some protected areas could be re-evaluated as useful tools/sites for these studies.

It should be necessary to increase the knowledge of population dynamics and/or ecology of key species in order to identify indicators suitable for detecting the fishing-induced changes.

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