ASSESSMENT AND MONITORING OF THE FISHERY RESOURCES
AND ECOSYSTEMS IN THE STRAITS OF SICILY

MiPAF

MedSudMed

GCP/RER/010/ITA

Report of the Expert Consultation on the Spatial Distribution of Demersal Resources in the Straits of Sicily and the Influence of Environmental Factors and Fishery Characteristics

Gzira, Malta, 10–12 December 2002

MedSudMed Technical Documents No.2
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Preface

The Regional Project "Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily" (MedSudMed) is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by the Italian Ministry of Agriculture and Forestry Policies (MiPAF).

MedSudMed promotes scientific cooperation between research institutions of the four participating countries (Republics of Italy, Libya, Malta and Tunisia), for the continuous and dynamic assessment and monitoring of the status of the fisheries resources and the ecosystems in this area of the Mediterranean.

Research activities and training are supported to increase and use knowledge on fisheries ecology and ecosystems, and to create a regional network of expertise. Particular attention is given to the technical coordination of the research activities between the countries, which should contribute to the implementation of the Ecosystem Approach to Fisheries. Consideration is also given to the development of an appropriate tool for the management and processing of data related to fisheries and their ecosystems.

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ABSTRACT

The first Expert Consultation, Spatial Distribution of Demersal Resources in the Straits of Sicily and the Influence of Environmental Factors and Fishery Characteristics, was held in Malta from 10 to 12 December 2002. All four MedSudMed countries (Tunisia, Malta, Libya, Italy) were represented, as well as colleagues from the Copemed Project and one external expert from the University of Plymouth. As agreed during the Coordination Committee meeting, the objective of the Expert Consultation was to provide an overview of available knowledge on the issue, draw up a programme for the activities to be implemented on the basis of common methodology, propose pilot study cases and identify needs in national and regional expertise. The technical contributions regarded four main themes: fishery biology, physical environment, biocenoses, and tools and data management. A synthesis was made by working groups who provided a summary of the available knowledge and data, a listing of the gaps and recommendations to fill these gaps. Discussions were conducted towards an agreement on an indicative work plan. The adoption of common methods and terminology was considered of utmost importance. The standardization of available data and sampling design also appeared as a priority.

Table of Contents

Report of the Expert Consultation on the Spatial Distribution of Demersal Resources in the Strait of Sicily and the Influence of Environmental Factors and Fishery Characteristics

Gzira, Malta, 10–12 December 2002

1. Opening of the consultation (Agenda Item 1)

The MedSudMed Expert Consultation on the Spatial Distribution of Demersal Resources in the Strait of Sicily and the Influence of Environmental Factors and Fishery Characteristics was held in Malta from 10 to 12 December 2002 and was hosted by the Ministry of Agriculture and Fisheries of the Republic of Malta.

The meeting was attended by experts from all MedSudMed Project participating countries, coming from research institutes of Tunisia, Malta, Italy and Libya, institutions and administrations. An extra-regional expert was also invited to participate in the consultation. Representatives from FAO (HQ) and FAO Regional Projects (ADRIAMED and COPEMED) were also present. The list of participants is in Annex A; the Agenda is in Annex B; the terms of reference of the consultation are in Annex C.

The meeting was opened by the Permanent Secretary of the Ministry of Agriculture and Fisheries, Dr Philip Von Brockdorff, and by the Director-General of the Fisheries Conservation and Control Division, Dr Anthony Gruppetta. Dr Von Brockdorff mentioned the international implementation of the ecosystem approach to fisheries, and referred more particularly to the challenges it sets for the General Fisheries Commission for the Mediterranean and its member countries. He underlined the distinctive nature of the central Mediterranean which appears to be a natural laboratory for the study of the interactions between fishery resources and the biotic and abiotic environment, and the fact that MedSudMed is a pioneer multidisciplinary Project to address these challenges. He then presented the situation in Malta, in terms of sustainable exploitation of fishery resources, which also benefited the adjacent zones by replenishing them by recruitment originating from Malta's 25-mile fishing zone. He recalled that, on Malta's accession to the European Union, this zone would retain its status with a special management regime within the framework of the EU Common Fisheries Policy. However, Malta and the EU have agreed that the resources and ecosystem therein should continue to be monitored, whilst obtaining new scientific evidence to update management regulations.

Dr Von Brockdorff stressed the fact that Malta looks forward to its active participation in MedSudMed, which will most certainly enable the further incorporation of the ecosystem approach into the fishery-management regime. Malta’s commitment to this will be highlighted in February 2003 when a public seminar on the ecosystem approach to fisheries will be held in Malta. This seminar is being organized and financed by APS Bank in collaboration with FAO and the Ministry of Agriculture and Fisheries. The Maltese interest in the MedSudMed Project was reflected in the participation of twelve experts from seven institutions specializing in different fields of marine science, which have been brought together by the Malta Centre for Fisheries Sciences. He concluded by thanking the Italian government and FAO and assured the participants that he would be following developments in the future activities of MedSudMed.

The Project Director, Fabio Massa, thanked the Ministry of Agriculture and Fisheries of Malta and the General-Directorate of the Fisheries Conservation and Control Division for hosting and supporting the meeting. He acknowledged all the researchers and research institutions of Tunisia, Malta, Libya and Italy for their attendance. He then opened the consultation, recalling the objectives and the expected outputs. The participants were also informed of the recent advances in the Project's activities, in particular the results of the 1st Coordination Committee meeting held in Rome (September 2002), during which, the general outline of the research to be implemented by the Project was discussed by the participating countries. The present expert consultation on the spatial distribution on demersal resources is a follow-up of this previous meeting.

The Scientific Co-ordinator underlined two points: (i) the fact that human activities were not the focus of the meeting, since several working groups are already dealing with this issue; (ii) the specificity of the present consultation and the output. The Scientific Director then justified the ecosystem approach to fisheries by two main arguments: (i) the failure of the traditional approach originally conceived by the fishery scientists of Russia, then of the North Sea countries, which raised the question of what else should be added to the traditional approach to improve the prediction of fish-population levels, and hence gave birth to such Projects as MedSudMed; (ii) the adoption of more-global approaches involving several natural sciences and even physics. However, the collaboration of different disciplines is difficult. Oceanographers and meteorologists, for example, have been called on to initiate such collaboration with fishery scientists, but past examples have revealed the difficulty. He gave the example of projects which needed years and hundreds of persons just to draw up the main lines of action, or others which are still in the preparatory phase after several years of work (e.g. the Mid-Atlantic Ridge Project). The Scientific Director therefore underlined the importance and ambition of a Project such as MedSudMed; he insisted on the multidisciplinary aspect of the present consultation and the fact that some of the presentations might also be useful for forthcoming expert consultations.

Experts from all the participating countries welcomed the initiative of the consultation and expressed their satisfaction that an occasion had thus been offered to discuss demersal resources at a regional level, and with multidisciplinary teams.

Sergio Ragonese was nominated Chairman of the consultation. He presented the Agenda (Annex B). The different points of the programme and the discussions are summarized in the sections below.

2. Organization of the consultation (Agenda Item 2)

The first part of the consultation was focused on the presentation of technical papers as national and international contributions to the knowledge of stock identity, ecosystem characteristics, given the meso-scale descriptions, and assessment of the relevance of a regional model. It was also stressed that the presentations do not represent the complete knowledge of the issues of concern, but are an important step for the Project in the achievement of its objectives as identified by the present consultation.

The second part of the consultation was dedicated to the synthesis of the presentations, with particular attention to the available knowledge and data. To this end, the participants split into four working groups which reported on their findings to the consultation.

The third part of the consultation focused on discussion of the priority activities to be co-ordinated and developed by the participating institutions. The discussions were based on the synthesis produced by the working groups; a general scheme was adopted, as well as proposals for training courses and standardization/harmonization of methods, and other relevant matters.

3. Experts' contributions (Agenda Item n. 3)

Since a number of advances have been made in understanding ecosystems, the presentations matched the terms of reference that had been drawn up for the present consultation (Annex C). Several presentations gave examples of applicable methods and/or tools. On the basis of the available data, a description of the biotic and abiotic characteristics of the region was also provided. Finally, policy and management considerations were also addressed, in the context of the ecosystem approach to fishery-resource management. Presentations were classified under four main themes: (i) fishery biology and characteristics; (ii) physical environment of the region; (iii) biocenoses; (iv) tools and data management. Following the presentations, general recommendations were made, on the basis of the authors' experience in specific disciplines, on the activities to be carried out in the framework of the MedSudMed Project. Abstracts of the remaining presentations are in Annex D.

3.1 Fishery biology and characteristics

A complete study of the cephalopod fisheries in southern Tunisia was presented; 32 species have been identified and mapped. Four species have been deeply studied, even though the common octopus is by far the most important in terms of abundance. The analysis explained the variability of the catches; it took into account fishing intensity, biological and ecological parameters (life history, behaviour, habitat etc.), predator–prey relationships, and topographical and hydrographical characteristics of the zone. However, further studies seem necessary, particularly those including environmental parameters.

The same observation can be made of crustaceans along the Tunisian coast. Around 15 species are regularly fished and commercialized; two of them have been studied more intensively (*Penaeus kerathurus* and *Parapenaeus longirostris*), and another two (*Palinurus elephas* and *Metapenaeus monoceros*) are presently under study. However, among other factors, environmental effects on spatial distribution are considered as one of the priorities for future study.

A summary of existing knowledge of some demersal fish species along the Tunisian coast was presented, based mainly on the stock assessment and experimental trawl surveys that were conducted between 1996 and 2002, in order to make up for a lack of data, which made management decisions difficult. A full description of the fishing fleet was made (technical characteristics, productivity and the size–age structure of the catches). Some of the studies focused on stock assessment, growth, reproduction, and feeding patterns of some 35 demersal species. The follow-up is to delimit the geographical distribution of these resources relative to the fisheries and the relevant environmental parameters.

Information on the spatial distribution and some biological characteristics of adults and recruits of some relevant demersal species along the coast of southern Sicily was presented. Information on growth, mortality, spawning, recruitment, sex-ratio and length–weight relationship is available for 18 demersal fishes. Distribution maps, as well as preliminary maps of the benthic biocenoses, were presented as information that could be taken into account in future studies of ecosystems.

In the other two participating countries, Libya and Malta, biomass indices and environmental measurements (CTD casts) along the Libyan coast for 1993 and 1994 were provided by the LibFish Project. Trawl-survey data were available for Maltese waters, as Malta has joined the international programme MEDITS (2000, 2001 and 2002); nevertheless, the coverage was very different from one year to the next because of the varying number of hauls. Therefore, according to the MEDITS sampling protocol, both a local (i.e. by haul) and a mean (by stratum and overall) index of abundance (expressed as no./km^2 and kg/km^2) are available for a series of target species.

3.2 Physical environment of the region

Meteorological data sets are available as part of the regional data inventory. These data were collected in Malta and include both atmospheric (wind speed and direction, air temperature, pressure etc.) and marine (sea temperature, salinity, gales, sea level etc.) parameters which were presented as possible factors influencing species richness, diversity and abundance. Long time-series are available, beginning in 1923 and ending in 2003, for the longest ones, and cover all the central Mediterranean.

A proposal was made to acquire the necessary understanding to predict the effect of the physical environment forcing on the marine ecosystem, at a mesoscale. The proposal strongly recommended the use of remote-sensing data (from AVHRR, SeaWiFS, MODIS, TOPEX/Poseidon, ERS and other satellite sensors): raw as well as archive data. These would be combined to produce Ekman maps and/or wind fields and subjected to image processing in order to enhance the gradients. Examples of illustrative and animated maps were shown. This work would develop the regional expertise in the acquisition, processing and forecasting of ocean mesoscale features for fishery monitoring purposes. Three modules were proposed: (i) data analysis for routine mapping and correlation with fish abundance; (ii) development of numerical techniques for forecasting mesoscale variability; (iii) continuous acquisition of physical oceanographic data.

3.3 Biocenoses

Two papers dealing with benthic habitats were presented, regarding Maltese and Tunisian waters, respectively. The first described past and on-going research on benthic habitat and biota in Maltese waters, and took stock of the situation based on past and on-going studies. The presentation focused on benthic surveys to provide a description and mapping of marine biotopes, the macrofauna associated with seagrass meadows, outer shelf (40–80 m depth) maerl beds and benthic assemblages in waters around Malta. More detailed investigations are still required for deep zones below 40 m depth, where gaps in knowledge of sea-bed and biotic assemblages are important.

The second paper presented similar studies along the Tunisian coast. It also reviewed research in Tunisia on the effects of human activities on the marine habitats. The results were obtained by qualitative studies of the macro- and megabenthos and seagrass meadows of the circa- and infralittoral zones. An exhaustive description of biodiversity in the Gulfs of Tunis, Hammamet and Gabès was made. Examples of human effects on benthic assemblages were also given, as well as the results of studies of rehabilitation of degraded zones.

3.4 Tools and data management

This session included eight contributions dealing with data-collection tools, data-base management, examples of data-processing methods, and availability and application of remote-sensing data and technology to the study of demersal resources.

An example of a spatial management tool was presented using scenarios based on data collected in Maltese waters: biomass indices, fishing methods, bottom types, bathymetry and historical data. Methods of compiling these data of different format, resolution and origin were presented. This example illustrated a tool that could be developed for use in the MedSudMed Data-Base and Information System, since it allows the management of different types of data (different formats and resolutions) which can then be represented using a geographical information system (GIS).

A fishing-survey data-management tool was presented by a representative of the COPEMED Project. An example of its application was shown using Tunisian data. This tool has two modules that allow the spatial analysis of abundance indicators and the calculation of an abundance index for a set of sampling stations that can be selected according to criteria set by the user. The overall structure, the GIS interface, and the types of statistics that can be computed were presented.

A study on spatial analysis of fishery data in relation to abiotic environmental factors was presented. Although the example presented was not within the MedSudMed Project area, the results were considered relevant to the present consultation. Trawl-survey data collected in the Strait of Malacca in the vicinity of Kelang (Malaysia) were related to abiotic factors such as salinity, temperature, turbidity, clay and silt percentage, organic-matter content, and pH of the sediments, using canonical correspondence analysis. Distributions were described according to the life stages and their tolerance to the environmental factors. The results were related to river discharges that affect the sediment distribution and water characteristics.

The next three presentations were oriented towards equipment and data-collection methods. Two of them provided a description of the technical characteristics of remote-sensing receiving stations (IcoD in Malta and IRMA in Italy). Examples of images or data that can be displayed and processed were given, in particular with respect to coastal dynamics, identification of thermal fronts, biological productivity, and human activities. Modern sensor systems that could be used were mentioned. The application of such data to research in fisheries was discussed.

Another intervention dealt with a tool that could usefully be used for the study of demersal-resource spatial distribution. The recently developed image-analysis software, Abiss, coupled to an underwater camera, overcomes common scale and perspective problems encountered when analysing underwater photographs. The sea bed can be explored in detail in the

framework of a benthic survey, provided that an ROV is available. Abiss was demonstrated to illustrate the possibilities of such a tool and the types of data that may be collected with it.

Finally, a procedure for preliminary data screening within the framework of the MedSudMed Data Base and Information System was presented. The data research was conducted with the ultimate goal of including these data in the MedSudMed System. Participants were invited to submit their requests to the Project, in order to have an indication of the data formats with a view to future integration of these data into the System. Participants agreed to this proposal and were informed that a form will be shortly sent to them by the Project, in order to list existing and required data bases for future activities.

Meanwhile, some of the most relevant web sites containing environmental data sets and covering the Mediterranean Sea and, in particular, the Project area were presented by a representative of the Project. A synthesis of the results showed a classification of the data sets in order of importance in terms of temporal and spatial coverage and resolution, and according to the variables available (temperature, salinity, water density, chlorophyll, currents, phosphate, silicate, nitrate, wind, dissolved oxygen, etc.). Examples of maps that can be drawn up with the extracted data were presented, using the comprehensive ocean–atmosphere data set (COADS) and the World Ocean Atlas–World Ocean Database (WOA–WOD). The differences in sampling coverage were shown, as well as the effect on the interpolation and mapping of the descriptors. Differences between the data sets were shown, as well as the advantages and the limitations of these data.

An additional presentation was then made on the viability of scouting less- or unexploited fishing grounds within the Project area. The basic aim of this presentation was to point out the possibility of diluting the present fishing effort by enlarging the exploitable area, and exploiting lower-value fish species, which would ultimately increase the yield of higher-value species. A feasibility study conducted in these less exploited areas would be an opportunity to collect additional information on the spatial distribution of fishery resources.

4. Reports of sessional working groups (Agenda Item 4)

On the basis of the 18 presentations, and in order to draw up a synthesis of the available knowledge and gaps, the consultation was organized in four thematic working groups. The themes were:

(i) Spatial distribution of target species
(ii) Benthic biocenoses and demersal fish assemblages
(iii) Physical description of the area
(iv) Fishing pressure on demersal resources.

The report of each working group was presented in plenary session. Each one was asked to produce a 2-page synthesis of the available knowledge at a regional level, according to what had been presented by the several authors and to what is available in the institutes. The working groups were also asked to: (i) identify and list the gaps in this knowledge, according to the objectives of the MedSudMed Project; (ii) propose ways of filling the gaps, in the framework of the Project; and (iii) with a view to providing input to the MedSudMed Data Base and Information System, indicate the needs in terms of data management (e.g. contents, structure and relationships of the data sets required to fulfil the objectives of the research).

4.1 Spatial distribution of target species

General information was given on the existing abundance indices, and the maps that are already in a GIS format. The different data bases cover periods starting from 1985, up to 2002, according to the zone and type of data. For all countries, even if the time periods do not always overlap, geo-referenced abundance data by species and size-class are available, as well as distribution maps in GIS format, as summarized in Table 1.

Table 1. Preliminary list of geo-referenced data sets available by species and size-class in the Project area

Country	Geo-referenced data	Maps (already in GIS format)
Italy	MEDITS spring surveys for 1994–2002: abundance indices for all 37 target species and by size-class for the most relevant species National surveys for 1985–2002: abundance indices for all relevant species and by size-class for the most important target species.	*Hake*: recruits; *red mullet*: recruits and adults; *greater forkbeard*: recruits *broadtail squid*: recruits and adults; *horned octopus*: recruits and adults
Libya	National trawl surveys from 1991 to 1993; abundance data by species not very regularly sampled	Abundance of hake, red mullet and others
Malta	MEDITS surveys from 2000 to 2002	Abundance of 37 target species by stratum
Tunisia	Old data (1980–1990) sporadic both in terms of space and time, but in any case abundance data by species. From 1996 to 2002, surveys with irregular periodicity (in different seasons and areas depending on the year) for all species listed in Tables shown in the three national contributions (on fishes, cephalopods, and crustaceans)	

Advantage can be taken of ongoing or previous FAO Projects, such as COPEMED, for the work achieved using GIS in areas that are also covered by the MedSudMed Project. Moreover, the LibFish Project conducted surveys at sea a few years ago along the Libyan coast, providing information on the abundance and distribution of demersal fish resources.

4.2 Benthic biocenoses and demersal fish assemblages

For most participating countries, partial description of the coastal biocenoses down to 50 m depth is available. For deeper water, the description of biocenoses and bottom types has been made possible thanks to trawl surveys. For instance, IRMA–CNR of Mazara del Vallo (2002) produced a qualitative biocenotic map of the trawlable soft bottom based on data from trawl survey programmes (GRUND, MEDITS). Moreover, for the Libyan shelf area, information on the bottom type (sandy, muddy, rocky) is available and was provided by trawl surveys.

Scattered and patchy information also exists on the benthic biocenoses of the hard bottom of the rocky banks (Adventure, Scherchi, Pantelleria) that characterize the central part of the Project area.

Some geological information (sedimentology, morphology of the sea bottom) is also available and could be a useful tool to validate data and information collected by the trawl surveys, in order to derive the biocenosis types.

Finally, the trawling grounds were described in the framework of the FAO LibFish Project, indicating the types of bottom, and localizing the trawlable grounds down to the 300-m isobath.

4.3 Physical description of the area

At a regional level, rough maps of seabed biotypes and sediments types provided by a Russian source are available, as well as historical and present remote-sensing observations (colour, sea-level anomaly, sea-surface temperature). Covering the whole Project area, there are also international data bases (Medar/Medatlas) providing hydrographic observations, as well as bathymetric maps at 0.5' resolution. Moreover, published literature provides synoptic weather patterns of the region. In most of the participating countries, data on meteorological parameters are also available, as well as subsurface currents in coastal areas, and surface and bottom temperatures where trawl surveys have been carried out.

In terms of capacity-building in the Project area, the working group noted the regional capacity to simulate and predict environmental conditions, both for the atmosphere (wind, air temperature, precipitation, etc.) and the ocean (3-D T/S, general circulation and wind-forced mesoscale signals). Other parameters, such as atmospheric dust loading/deposition, are also being monitored and modelled.

4.4 Fishing pressure on demersal resources

Each participating country has provided a description of its national fishing fleet, giving the number of boats and their principal characteristics (e.g. power of the engine, types of fishing gear and the corresponding target species. For each target species, mention is made of associated species, including those in the discards and the by-catches. When available, information on the periods of fishery closure is mentioned and the fishing grounds are localized within their respective geographical sub-areas. Therefore, part of the data is geo-referenced, giving the activity of the fleet in the different fishing grounds and according to the season, when available.

5. Synthesis of the gaps in knowledge (Agenda Item 5)

As regards biological and fishery data, the working groups underlined the absence of a consistent regional data set for the whole region that would allow spatial analysis. There is very limited information on the spatio-temporal variability in fish distribution, and therefore a poor possibility of acquiring a dynamic picture of the processes involved. The available samples are characterized by their spatial heterogeneity, both horizontally and vertically. The

lack of seasonal data covering spawning and recruitment periods was also highlighted, as well as the absence of samples in areas that are not accessible to trawling. It appears that, for most species, a proper identification of spawning, nursery and feeding areas should be made. Another gap concerns specific feeding habits and trophic interactions, although these can have an important impact on fishery resources. There are few published data on these aspects; trawl surveys might be a source of information, but ad hoc studies must be carried out for a proper treatment of stomach-content samples.

From a fishery point of view, an important lack of geo-referenced data on the fishing effort was underlined. One possibility suggested to overcome this lack was the use of proxies for sensitive species. Also, some important gaps remain in respect of the fish assemblages characterizing the main fishing grounds. In the same way, very little information is available for mapping marine habitats and communities. Below 50 m depth and for hard bottoms (in zones where no trawling has been carried out), there is no fully regional biocenotic map with a good resolution, the existing information being relatively scattered.

In the same way, the lack of high-resolution data on sediment types and biotypes was highlighted, and acoustic surveys were recommended to overcome this lack. The need to improve baseline data, particularly current measurements, was generally advised.

In terms of capacity-building in the Project area, the limited number of physical oceanographers in the institutes in the area was underlined, as well as the difference in expertise in numerical-modeling techniques among the participating institutions. However, the working groups recognized the regional capacity to simulate and predict environmental conditions, both in the atmosphere and in the ocean, even though this capacity needs to be improved, in particular with respect to coupling the information with biological observations. This seems to be due mainly to the lack of knowledge of physical forcing on ecosystem functioning and biogeochemical cycles.

6. Synthesis of the recommendations (Agenda Item 6)

Following the identification of the gaps, the participants drew up recommendations on the regional activities relevant to the determination of the spatial distribution of the demersal resources in the MedSudMed Project area. These recommendations covered the areas to be studied and the types of study to be conducted. The adoption of common methods and terminology was considered of utmost importance for all types of information to be processed. Methods to be used for future data collection were also indicated.

The recommendations can be summarized as follows:

- Identification of specific areas for the conduct of pilot studies, using existing data, and for the collection of new data/information
- Adoption of a common cartography
- Standardization (sampling, data processing) of:
    - Trawl-survey data (seminar)
    - Biocenosis data (using the RAC/SPA classification)
    - Remote-sensing data (standardized formats to allow the data exchange)

- Use of data from fishing with other gears, such as longlines, gill nets, traps, trammel nets, to overcome the lack of samples in non-trawlable areas
- Collation of existing data on biocenoses
- Need for homogeneous data formats, in order for data to be entered in a common data base that would facilitate the management and exchange of the information
- Future collection of data on:
    - Biocenoses (using sonar, video, grab sampling, etc.)
    - Sediments types and biotypes (using acoustic surveys to collect information on the bottom)
    - Currents (to improve baseline data)
    - Spatial distribution of fishing effort (using blue box, logbooks, biological indices)
- Development of indices of environmental conditions to be applied to fishery recruitment and population dynamics

7. Indicative work plan and activities (Agenda Item 7)

Standardization of the data was pointed out as an important issue. It was agreed to take into account international classifications (e.g. for biocenoses and habitats), when they exist, and reorganize the data accordingly. If national sampling protocols are currently in use, standardization working groups should be organized in order to harmonize methods at a regional level. The particular case of trawl surveys calls for an ad hoc seminar on the various steps in the data acquisition and handling:

- sampling design
- equipment to be used
- species to be sampled
- handling of the samples
- collection of biological information on the samples
- data processing and management
- calculation of biomass indices.

The participants agreed to adopt a common cartography, preferably using the Mercator projection. Maps should be prepared with all relevant available data, using a GIS, according to the scheme shown in Figure 1. All participating institutes should use the ArcView Programme, with the same digital-map basis.

The different available data sets will be used to draw single thematic maps, using the same interpolation methods throughout the region. Advice will be taken to list in order of priority the abiotic parameters to be used to obtain a preliminary picture of the area. Fishery data will also be mapped; target species, as well as the type of information to be included (life stages, abundance, etc.), will be agreed upon during the proposed standardization seminar.

This preliminary work will facilitate the highlighting and the characterization of particular zones in the Project area. This will help the Project to concentrate on specific areas which

show physical and biological peculiarities that may explain the spatial distribution of demersal resource species. A set of oceanographic parameters will be built up for each station (temperature, dissolved oxygen, etc.) to be associated with the abundance and demographic parameter estimates (biomass index for adults and juveniles, density index, sex ratio, size composition, etc.) for specific demersal target species. A preliminary analysis by target species, and at multispecies level, will be made to highlight sub-areas where homogeneous conditions prevail, even considering the specific oriented fishing effort. In particular, spatial distribution of fish assemblages will be described. The next step will be to draw up a hypothesis to be tested for each target species/life stage. Three or four of these sub-areas will then be chosen for a pilot study, to check the hypothesis and to build up a synthetic model. These successive steps will help to find the links between environmental variables and fish assemblages, and would allow the computation of predictive correlations between the dynamics of a given target species and easy-to-measure environmental variables.

This phase of the work should be achieved within one year. The expected output is a full synthesis of the available information presented in a GIS module that will present the same formats in all participating institutes, so as to allow the comparison of the data.

Ultimately, abundance and spatial distribution of fish should be linked to biotic and abiotic parameters that will be identified as possible indicators for the monitoring of the resources. This will be done by analytical processing of the data and numerical modeling at a regional level, and will be implemented in the second phase of the present activity through regional working groups.

Data processing should be performed using common formats and information. Therefore, an effort will be made to produce a homogeneous data base, with the proviso that confidential or private data be accessible only to the respective owners. However, despite confidentiality of the data, it is of utmost importance to have knowledge of the structure and format of existing data in order to allow comparisons of scientific studies at a regional level. The Project will create an inventory; it will send forms to all the participants in the present consultation, with a view to collecting information on existing data. Moreover, these forms will offer the participants the possibility of requesting specific data that they need to fill any gaps in their scientific information. The regional working groups will also be charged with providing the Project detailed information on data formats, with a view to building, step by step, the regional Data Base and Information System.

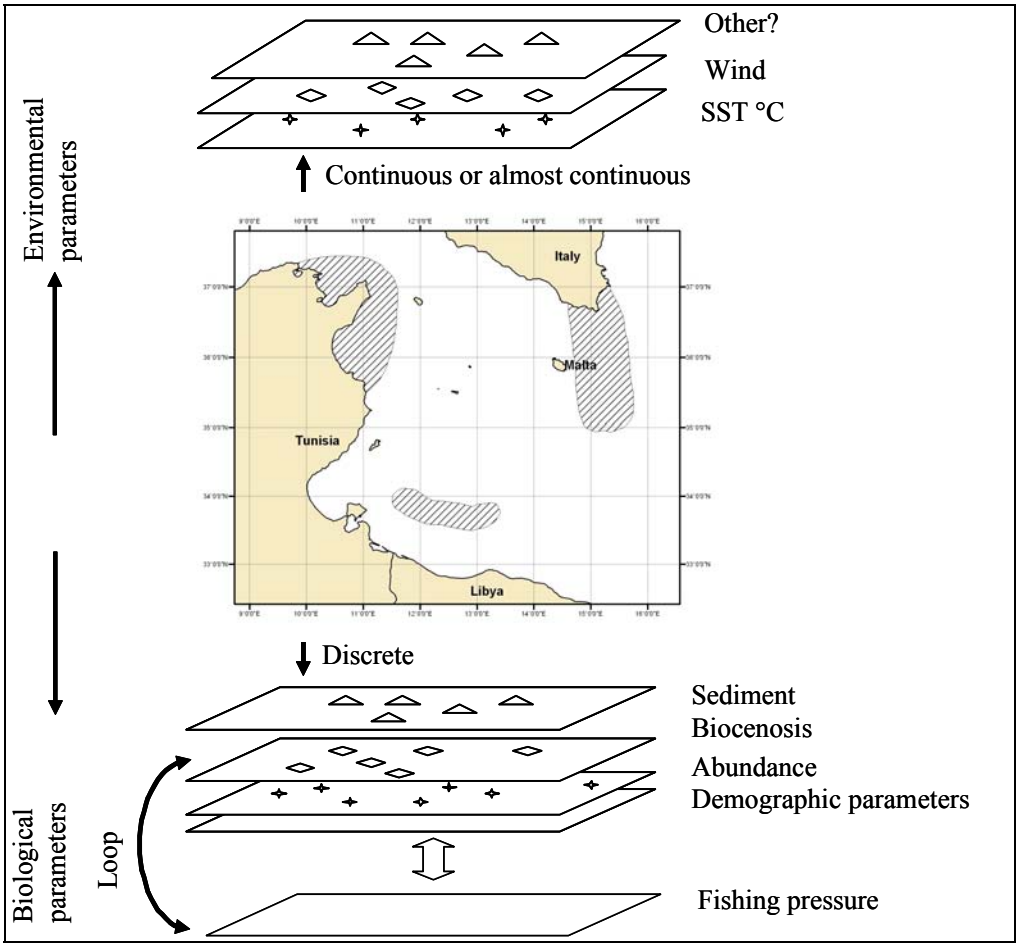

Figure 1. Preparation of the information and the highlighting of homogeneous sub-areas (hatched)

The results of the present consultation will be brought to the knowledge of the forthcoming expert consultations, to ensure that any information that might be relevant to another consultation will be presented. Therefore, at the beginning of each forthcoming consultation, a synthesis of the preceding consultations will be presented, in the interest of coherence of the Project's activities and to avoid any overlapping.

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Annex B: Agenda

1. Opening of the consultation
2. Organization of the consultation
3. Experts' contributions
4. Reports of sessional working groups
5. Synthesis of the gaps in knowledge
6. Synthesis of the recommendations
7. Indicative work plan and activities

Annex C: Terms of reference of the MedSudMed Expert Consultation on the Spatial Distribution of Demersal Resources in the Strait of Sicily and the Influence of Environmental Factors and Fishery Characteristics

1. Background and general information

As a consequence of the technical guidelines produced by FAO in support of the implementation of the Code of Conduct for Responsible Fisheries, research to increase knowledge using the ecosystem approach to fisheries is becoming a priority. This was further underlined and strongly recommended by the Declaration of the Reykjavik Conference (on Responsible Fishing in the Marine Ecosystem, October 2001), which encourages the incorporation of ecosystem considerations into fishery management, particularly by *building expertise for collecting and processing the biological, oceanographic, ecological and fisheries data for designing, implementing and upgrading management strategies*.

In this line, the FAO Trust Funds Regional Project MedSudMed on Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Strait of Sicily is aimed at supporting scientific communities and countries in the development of a monitoring system for studies of the fishery resources and the ecosystems. The main objectives of the Project are to increase scientific knowledge of the Strait of Sicily ecosystem, strengthen national and regional expertise, develop scientific co-operation in the standardization of the methods used in the fishery research.

During the 1st Meeting of the MedSudMed Coordination Committee (Rome, Italy, 19–20 September 2002), a general outline of research and the activities to be implemented by the Project were discussed. A preliminary plan was presented for research aimed at improving information resources for fishery management, biodiversity protection, and ecosystem preservation in the Strait of Sicily. It was focused on three main proposals: (i) Spatial distribution of demersal resources according to environmental and fishery features; (ii) Small pelagic fish in the Strait of Sicily: stock identification and oceanographic processes influencing their abundance and distribution; and (iii) Marine protected areas and fishery management.

The MedSudMed Project, for each of the three research topics, decided to organize an expert consultation in order to acquire an overview of available knowledge on fishery ecology in the region. The expert consultations will involve regional and extra-regional experts and will provide an overview of available knowledge on the issues addressed. The aims of the expert consultations are the definition of a work programme on the basis of a common methodology and proposals for pilot studies. Furthermore, the expert consultations should also identify needs for national and regional expertise, provide the opportunity to define criteria for the data collection, and identify a task leader who will co-ordinate the agreed programme of work.

The present consultation is the first one organized by the Project.

2. The purpose of the consultation

The consultation will explore all facets of the spatial description of fish stocks in the Strait of Sicily, in an attempt to arrive at a complete synthesis of existing knowledge of the different species, and the identification of the gaps in knowledge that still need to be filled. National contributions are requested in the form of a written synthesis to be presented during the consultation. They should consist of a broad description of the fisheries that depend upon the demersal resources, as well as the results of the studies conducted on these resources and their environment. Therefore, the synthesis should be based on all available fishery, biological, ecological, physical and, when applicable, socio-economic data related to the demersal resources. Proposals for future work should also be presented (bibliographic syntheses, data treatment, field operations). This would facilitate the listing of the gaps in knowledge, and the drawing up of a work programme agreed by all the participating countries.

3. Focus and issues to be addressed

The expert consultation should focus on the description of the spatial distribution of demersal resources in the Strait of Sicily and on the factors affecting/explaining this distribution (environmental parameters and fishery characteristics); the different life stages of commercial fishes should be considered (recruits, juveniles, adults), in particular of species considered as forming shared stocks and those supposed to belong to separate stocks. This should contribute to improving the knowledge of the recognition and delimitation of the different stocks in the region.

As mentioned in the research proposal corresponding to the present consultation, the different themes that should be addressed are:

- The physical environment of the region; this comprises hydrographical characteristics, bathymetry, sedimentology, habitat mapping, typology of bottom grounds
- Availability of elements of distribution of fish species (single species or assemblages), localization of feeding, spawning and reproduction areas
- Known ecology/biology of the main commercial species
- Possible migration patterns and the types of migration
- The fishery: seasonality, quantification and spatial distribution of the fishing effort, fishing techniques used in the region
- Availability of data that can be exploited for further results
- Possible combinations of the type of information cited above, giving an idea of the possible interactions between demersal resources and environmental parameters (biotic and abiotic)
- Relevant methods, equipment and techniques for data collection or treatment regarding demersal resources, fisheries and/or environment
- Geographical information systems.

4. Expected outputs

- Synthesis of the available knowledge: compilation of the national contributions will give an overall idea of the present level of knowledge, with indications on stock

identification, ecosystem characteristics, given the meso-scale descriptions, and assessment of the relevance of a regional model.

- Identification of gaps: questions that are still not solved will be raised. This would help define the scientific hypothesis to be verified by the research, in order to have a clear programme of research to follow. Moreover, listing the lacking data will help in defining a data-collection scheme, calendar and cost, in order to assess the feasibility of all proposed research. These elements (scientific hypothesis, availability of data, cost of possible activities) will determine the topics to focus on, as well as a reasonable calendar of activities that fits the budget of the Project.
- Methodology to fill the gaps: the ad hoc methodology will be discussed and agreed upon, knowing that existing information can be processed, by technical working groups and/or contracted expert(s), or data collection may be organized according to the on-going studies in the participating countries (type of sampling, calendars, comparative studies).
- Data-management needs in terms of content, structures and relationships
- Pilot studies
- Needs in regional and national expertise
- Creation of a regional network of multidisciplinary experts, to be involved in the MedSudMed activities related to the present consultation.

The report on the expert consultation will be published as a Technical Document of the MedSudMed Project and will be available as an information paper for the GFCM's Scientific Advisory Committee and its sub-committees on Ecosystems and Marine Environment and on Stock Assessment, as well as for other relevant regional meetings and bodies relevant to the issues addressed.

5. Participation

The expert consultation will involve regional and extra-regional experts. The participants will have a broad disciplinary background; it is of utmost importance that persons with different skills be brought together to share their knowledge and experience.

Discussions will be led by the Scientific Director of the Project, Project staff and experts participating in the consultation. An international expert could be invited to participate in the consultation and in the preparation of the final report.

The expert consultation will be conducted in English.

6. Organization of the consultation

The expert consultation will be convened by the Government of Malta in co-operation with FAO. It will be held at the Waterfront Hotel, Sliema, Malta, from 10 to 12 December 2002, inclusive. Participation is by invitation only. All costs will be borne by the MedSudMed Project.

Influence of environmental parameters and fishery on demersal fish distribution along the Tunisian coast

Othman Jarboui* and Amor El Abed

Abstract

According to the latest FAO statistics, since the 1990s, the world production has shown a trend to decrease which differs from one area to another and from one group of species to another. This trend can be essentially explained by the progressive increase in, and the inefficient control of, the fishing effort. Indeed, according to the Reykjavik Conference on Responsible Fishing in the Marine Ecosystems, October 2001, more than half of the fisheries in the world have been fully exploited, a quarter have been overexploited and the remaining quarter would not withstand a higher level of exploitation. This situation is most marked in the Mediterranean, which is a semi-enclosed sea. Indeed, the productivity of the majority of fishing units is continually decreasing and a majority of the demersal stocks are either fully exploited or overexploited.

This overexploitation of marine resources in the world is probably due particularly to the ineffectiveness of present classical management measures, which consider the exploitable marine resources independently of their habitats and without taking into account the ecosystems in which they live. Nowadays, the marine ecosystems, as well as the impact of fishing on their structure, arouse a growing interest.

In Tunisia, in recent years, the Laboratory of Living Marine Resources of the National Institute of Marine Sciences and Technology (INSTM) has carried out an important number of stock assessments. Initially, the National Research Programme on the Evaluation of the Tunisian Marine Fishery Resources considered about 20 demersal species and lasted from 1996 to 1999. In a second phase, these assessments were strengthened and completed by the launching, in 1999, of a new Research Programme that considered more than 15 new exploited species. These research programmes mainly dealt with:

- **The typology of the Tunisian fishing fleet:** For the first time in Tunisia, it was possible to record the totality of the fishing fleet operating along all the Tunisian coast. We were also able to collect and analyse all the information relative to this fleet, such as vessel characteristics (size, strength, tonnage, age, material of construction), the fishing activity (fishing gears, fishing period, fishing zone, commercialization of the catch) and the production (fished species, fished quantities, output of boats, etc.). All this detailed information was recorded in a data base and can be updated whenever necessary. In 1998, the data were transmitted to the Ministry of Agriculture (General Direction of Fishing and Aquaculture, DGPA) which took the responsibility for maintaining the data base and updating it whenever a change occurs.
- **The analysis of the present fishing systems:** During a consecutive period of two years, we established a permanent network of investigators in about 30 fishing harbours and landing points, with the collaboration of the Ministry of Agriculture and

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the fishery professionals (UTAP). The tasks of these investigators were to regularly follow up the fishing activity of a representative sample of the fishing fleet and record all information relative to the fishing effort, production and size/age composition of the main species. Thanks to this operation, we collected more than 40,000 technical information sheets. All this information was organized in a data base that provided the following results ventilated by area, species, fishing gear and season:

- ♦ Evaluation of the production of all species fished along the Tunisian coast; the gathered data were used as an input parameter of the stock-assessment model for pseudocohort analysis
- ♦ Daily productivity per boat
- ♦ Size/age composition of the catch of the studied species.

- **The biological study of the main exploited species**: The biological study considered more than 40 species recommended by the professionals. To this end, 10,000 marine organisms have been dissected. Growth, reproduction and diet were the main parameters studied. For each species, the most important results were recorded on a Biological Identity Sheet. These results were communicated to the Ministry of Agriculture in order to elaborate legislation on the authorized minimum catch size and the fishing periods, based on recommendations made by the Research Institute. Finally, it is important to stress that these biological results are very important to the understanding of the interactions between the species and the marine ecosystems in the Tunisian fisheries. They are also useful as input parameters for the mathematical models used to assess the main exploited demersal stocks.
- **The stock assessment**: The dynamical study consists particularly in evaluating the state of exploitation (fully, under- or over-exploited) of the most studied species. Up to now, we have been able to study 29 demersal species and 10 pelagic species.
- **The spatio-temporal distribution of the exploitable fishery resources along the Tunisian coast**: The experimental trawl survey is important for the development of the fishing sector. Indeed, it allows us to determine densities and the spatio-temporal distributions in different prospected zones. These operations along the Tunisian coast started in 1998, thanks to the new research vessel "Hannibal". More than 10 experimental trawling surveys and more than 700 experimental trawling operations were executed from 1998 to 2002. To study biodiversity and the quality of the environment in the fishing zones, we took advantage of each survey to collect samples of water, sediments and marine organisms. We organized a data base that will allow us to evaluate the influence of environmental parameters and of the fishery on the spatial distribution of the marine resources.

In the future, this prospecting and experimental trawling will be strengthened, as well as the setting of national and regional programmes. Indeed, this remains the appropriate method for understanding the climatic and the environmental factors that are important in the spatio-temporal distribution of demersal fishes.

Regarding the MedSudMed Project, in particular the component Spatial Distribution of Demersal Resources in the Strait of Sicily and the Influence of Environmental Parameters and Fishery Characteristics, an adequate research programme should cover the main objectives of

the Project, the survey zone, the material and the necessary means, and the methodology used.

The objectives should be clearly identified; the influence of the environmental factors and the fisheries on the marine ecosystems in the study area should be stressed. The study area should also be clearly defined and should take into account the existing geographical delimitation of Management Units in the Mediterranean, as defined by the Scientific Advisory Committee (SAC) of the GFCM.

With regard to the material aspects of the survey, the fundamental means remains the research vessel. Indeed, every research team participating in this project should organize a seagoing research unit, in order to conduct the different experimental trawl surveys that will be scheduled in the study area. These research vessels should be the most coherent possible among the participant teams. On the Tunisian side, the R.V. "Hannibal" is used for our trawling and prospecting operations. Besides, the fishing gear that will be used in the different experimental trawling operations should be the same for all the research teams. A trawl with a large vertical opening would be a good choice.

The adopted sampling protocol and the methodology used should be standardized initially among the different research teams. For this, a stratified sampling protocol according to the depth could give good results. Regarding the use of the swept-area method, some scientists express reserve essentially because of the difficulty in evaluating escapement factors relevant to the different species studied; these factors should be carefully analysed.

The effects of environmental factors on the distribution of crustaceans along the Tunisian coast

Hechmi Missaoui*

Abstract

About twenty commercial crustacean species are caught in Tunisian fisheries: *Palinurus elephas* (red lobster), *Palinurus mauritanicus* (white lobster), *Nephrops norvegicus* (Norway lobster), *Homarus gammarus* (European lobster), *Scyllarides latus* (Mediterranean locust lobster), *Scyllarus arctus* (small European locust lobster), *Penaeus kerathurus* (camarote prawn), *Parapenaeus longirostris* (deep-water pink shrimp), *Aristaeomorpha foliacea* (giant red shrimp), *Aristeus antennatus* (blue and red shrimp), *Plesionika martia* (golden shrimp), *P. edwardsi* (striped soldier shrimp) and *P. heterocarpus* (arrow shrimp), *Metapenaeus monoceros* (speckled shrimp), *Trachypenaeus curvirostris,* (southern rough shrimp), *Alpheus glaber* (red snapping shrimp), *Pontocaris lacazei* (hardshell shrimp), *Maia squinado* (spinous spider crab) and *Carcinus maenas* (green crab).

The distribution of these species differs according to depth, temperature, nature of the sea bottom, sensitivity to pollution. Some species are concentrated on the northern side of the country, such as the red, European and Norway lobsters, and the deep-water shrimps (*Parapenaeus longirostris, Aristeus antennatus, Aristaeomorpha foliacea,* and *Plesionika* spp.). The shrimps *Penaeus kerathurus* and *Metapenaeus monoceros*, which have recently migrated from the Red Sea, are concentrated on the southern side of the country.

The bio-ecology of crustaceans has been little studied. Research was concentrated on *Parapenaeus longirostris* and *Penaeus kerathurus* because of the important landings of these species. Biological parameters of *Penaeus kerathurus* and the biometric relations of *Parapenaeus longirostris* and *Palinurus elephas* were determined. Stock assessments using production models to estimate the MSY for *Penaeus* and *Parapenaeus longirostris* stocks were carried out. It should also be pointed out that the biological sampling is very difficult for many species (*Palinurus elephas*, *Homarus gammarus*, *Nephrops norvegicus, Aristeus antennatus, Aristaeomorpha foliacea, etc.*).

Much more research is needed to acquire a better knowledge of the distribution and dynamics of the crustacean species exploited in Tunisia. But collaboration with professional fishermen in the fishing areas and with the fishery administration is essential.

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Distribution and abundance of the demersal fish community in Klang Strait (Malaysia) in relation to environmental factors

Salem W. Zgozi*

Abstract

Demersal fish distribution and abundance in Klang Strait were studied, based on trawl surveys with measurement of water and sediment characteristics; the studies were carried out from November 1996 to 1998. A total of 90 species belonging to 45 families were recorded, based on 9,269 specimens examined. The most common families were: Sciaenidae, Leiognathidae, Ariidae, Dasyatidae, Cynoglossidae, Gerridae, Mullidae, Platycephalidae, Pomadasyidae and Siganidae. Most of the species were represented by young juveniles. Multivariate analyses were carried out, and the relationship between the distribution and abundance of demersal fishes, and thirteen abiotic factors, was examined. Canonical correspondence analysis indicated that the most important abiotic factors controlling the distribution and abundance of demersal fishes were water salinity, turbidity, clay content (%), organic matter content and silt content (%).

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Viability of exploiting virgin trawlable fishing areas

Charles Busuttil*

Abstract

The main reason for the alarming depletion of stocks of prized demersal species, such as king prawns, prawns and other crustaceans, red mullet, hake and the common pandora, amongst others, is the intensive exploitation through trawling of known areas where there is a strong aggregation of these species. This situation is the result of the present marketing system, in which, only highly commercial species are presented for sale whilst less prized, though equally tasteful and satisfying, species are sidelined.

In the meantime, however, stocks of other edible fishes, such as skates and rays, dogfish, horse mackerel and bogue, are often returned to the sea, with negative results regarding their sustainability, which, owing to the inevitable eventual disappearance of the main targeted species, would have to be relied upon in future to supply the market.

It is a known fact that certain areas of the central Mediterranean, which up to some years ago used to yield commercial quantities of some of the above-mentioned species, are no longer being visited, the simple reason being that there are no more fish to be caught.

Unfortunately, owing to economic exigencies of boat owners, there may not be a short-term alternative to this situation, but a long-term alternative could be the exploitation of other trawlable unfished zones in the central Mediterranean. Another alternative would be the curtailment, by legislation, of trawling in particularly sensitive areas, but that may be too drastic. Ideally trawlers should conduct scouting operations to find new areas on their own, as indeed some of them actually do.

However, with regard to the exploitation of new areas, the main difficulty is that the initial yield would lack large quantities of higher-valued species, particularly crustaceans, since these will only be present in commercially viable quantities after the area has been cleared of other species, such as skates and rays, monkfish, dogfish etc., which tend to leave the area when trawling becomes regular; but this would take some time and, as a consequence, it might mean loss of earnings for the boats concerned.

For this reason it is suggested that an exploratory scientific and simulated commercial trawl survey of these virgin zones be undertaken along the lines of the Malta FAO-funded project in 1976–77 in the central Mediterranean, as a result of which, quite a few new trawlable areas were found.

One particular area which was surveyed and exploited by the survey vessel during the above-mentioned period, and later on by other Maltese-registered trawlers, is about 63 miles south of Malta, 72 miles east of Lampedusa Island and about 160 miles off the coast of Libya. The approximate surface area is about 500 square miles. All over this area, the composition of the bottom is sedimentary, with a predominance of yellow mud, which makes for excellent trawlability. Only one obstacle, which was recorded, was encountered, thus rendering

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operations trouble-free. The bottom is also flat, having a very slight gradient, and depths are constant. Trawling was undertaken in the 200–400 m depth interval, and landings, given the pristine state of the area, were substantial for prized species, whilst other less-valued species were quite abundant, as the following table of the general hourly catch shows:

Table 1. Hourly catches in the trawl surveys performed during the FAO–Malta field project in 1976–1977 in the central Mediterranean.

Species	**Hourly catch (kg/h)**
Commercial species :	
Horse mackerel	41.55
Mackerel	0.12
Red mullet	11.80
Hake	1.86
John Dory	0.52
Angler fish	1.00
Gurnard	2.55
Grouper	0.08
Angel fish	0.15
Dogfish	6.73
Ray/skate	17.41
Shark	0.03
Octopus	3.32
Squid	3.16
Shrimp	2.08
Norway lobster	2.84
Pistin (sparids)	0.09
Mixed comm. fishes	1.45
	Total = 97.64
Non-commercial: fish edible	26.94
Non commercial: fish inedible	13.13
	Total = 40.07

Also, trawling operations were undertaken both during day and night and although in certain areas there was a net decrease in catches at night, in other areas variations in catches were hardly noticeable. In fact, the prospect of being able to undertake trawling 24 h a day makes for lucrative operations in terms of savings in fuel consumption and more remunerative working hours, whilst the fact that 3 to 4-h trawls can normally be undertaken makes other work, such as selection of the catch and storing of fish, less stressful.

Within this zone there are areas that are deeper than 400 m, where trawlability is also excellent and the prospect of king prawns being present is quite real.

Results of such a survey would provide most experts dealing with demersal resources with, amongst other things, an opportunity to enhance their present studies; prospective captains and fishermen could be given training in navigational, trawling, and other relevant techniques

and also afford enough information to be useful when long-/short-term decisions on fishery management have to be taken.

In the meantime an educational/promotional drive through the media, which would highlight the nutritional value of the other "non-marketable" species, might create a market that could become lucrative, perhaps through quantity rather than quality, and in this regard also help the artisanal fishery, particularly for Malta, where species, such as skates, rays and dogfish, are still marketable to a certain degree.

Maltese offshore benthic habitats and biota

Patrick J. Schembri*

Abstract

Research work carried out by the Marine Ecology Research Group (MERG) at the Department of Biology, University of Malta, focuses on four areas: (1) inventories of selected groups of marine invertebrates; (2) studies of the ecology of particular habitats; (3) general biology of selected species of marine animals; (4) human impact on local ecosystems. Some past projects, which are relevant to the present expert consultation, are to be reviewed. These include: a pilot study on the evaluation, designation and management of a Marine Conservation Area on the NW coast of Malta, as part of the Coastal Area Management Programme for Malta (CAMP–Malta) financed by the UNEP Mediterranean Action Plan; research on seagrass ecosystems, particularly on the macrofauna associated with meadows of *Posidonia oceanica*; the BIOMAERL project funded by the European Commission of the European Union, in which the biodiversity, functional structure and conservation of a Maltese deep-water maerl ground was investigated; and the MAT project funded by UNESCO, in which the benthic assemblages of the lower infralittoral to upper circalittoral transition zone were studied by means of video transects.

Gaps and problems concerning knowledge of the benthic biotopes and biocoenoses of the Maltese Islands are identified. These include: poor knowledge of many groups of benthic organisms; lack of local taxonomic expertise and of taxonomic resources; limited benthic-habitat mapping, especially for deep water; limited human and material resources; and lack of research vessels.

It is proposed to carry out a more detailed investigation of the deeperwater benthic assemblages of the Maltese Islands than has hitherto been possible with the available equipment and techniques. This would extend scientific knowledge of the sea bed and its biotic assemblages and other resources to depths greater than 40 m, the limit of present capability using SCUBA. The expected outputs would be to: (1) map the bottom types present in deeper water; (2) discover the nature of the biotic assemblages they support; (3) assess their importance as fishery and other resources; (4) assess any impacts of human activities on these bottom types and their biota; and (5) make recommendations for their conservation.

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Acquisition and analysis of benthic photographs

Derek Pilgrim*

Abstract

It is proposed that the MedSudMed Project should include the acquisition and analysis of seabed images in Maltese waters and at selected sites elsewhere in the Project area. These images would make a significant contribution to the study of the benthic biology of the region and hence to the spatial distribution of demersal resources and the influence of environmental factors and fishery characteristics.

The analysis of underwater photographs in the study of seabed phenomena is a technique that has been in common use since the 1940s. However, there is a major problem associated with the analysis of seabed photographs: the unknown scale and perspective (effectively, a change in scale across an oblique image). This problem has now been solved at the University of Plymouth with the development of ABISS (Autonomous Benthic Image Scaling System). In this system, the underwater camera is fitted with five diode lasers which project a pattern of five spots onto the seabed. Subsequent analysis of the altered configuration of this pattern on the acquired image, using the associated ABISS software, enables scaling of the whole image. The software programme includes facilities for measuring lengths, areas etc. on the image. It also includes a range of image-enhancement functions for detailed study of image features. A successful PhD research programme involving benthic biological surveys of Plymouth Sound and Loch CreeNan (Scotland) has been completed using ABISS. The ABISS system may be further developed to fit any particular needs of MedSudMed. It is proposed that all acquired images be made available to participants through the Project GIS.

Careful consideration will need to be given to the choice of platform deployed to carry the camera and any other sensors (e.g. TS, transmissometer etc). Suitable possibilities include: remotely operated vehicle, towed sledge, lander and dipping camera, and these will be reviewed at the present consultation. There will be particular problems associated with working in deep water, such as high ambient pressures and the need for long and heavy umbilicals/cables.

It may be extremely useful to utilize the RoxAnn system which, connected to a standard single-beam echosounder, uses the first and second echo returns to discriminate between seabed material types. There are several published papers that describe projects in which these acoustic “material types” (essentially a combination of bottom roughness and bottom hardness) have been related to ecological habitats.

Clearly, the Project area is vast in benthic survey terms and we shall need to design a realistic survey/sampling strategy based upon priority biological questions and fieldwork limitations.

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Mapping of the hydrographical characteristics relevant to fisheries in the vicinity of the Maltese Islands

Aldo Drago*

Abstract

An ecosystem-based approach to the management of fish resources calls for a more profound understanding of the ecosystem component interactions and functioning, including an improved capacity to predict, with sufficient reliability, the response to forcings, in particular by the physical environment. The persistent oceanic systems driving the transfer of heat and momentum, cause water masses to mix, carrying biotic material and shaping phytoplanktonic biomass distributions which have an important bearing on biological processes, in particular on the transit paths and locations of pelagic fishes. Movements of fish are strongly connected to the physical characteristics and dynamics of the water body in which they reside, and are strongly correlated with temperature fronts, borders of flow, and zones of divergence and convergence.

A deeper insight into and concrete quantification of such relationships can furnish essential indicators for the conservation and sustainable use of marine living resources, as well as provide a better understanding of threats to stocks and biodiversity. The highly active mesoscale variability in the Strait of Sicily and the particular position of the Maltese Islands with respect to the swift Atlantic Ionian Stream make this sea area ideal for such studies.

The main aims of the proposed work are to: (1) assess and improve knowledge of the relationships between bioproductivity and physico-chemical conditions of the marine environment; and (2) develop a local capability to acquire, analyse and predict ocean mesoscale features as a basis and potential for fishery forecasts. The proposed methodology consists of three mutually supportive and complementary modules making use of remotely sensed information, numerical modelling, and in situ observations. In more detail, the proposed modules consist of:

- Analysis of near-real-time multi-spectral data (thermal and optical satellite images) for the routine mapping of relevant physical processes in the oceanic ecosystem, and establishment of their correlation with pelagic fish abundance; the focus would be on the integration of fishery data for a joint analysis using remote sensing, meteo and model data to develop algorithms for the tracking of fish stocks, through the elaboration of sea-surface temperature and chlorophyll distributions, position and displacement of frontal zones and mesoscale structures (eddies, jets, upwellings, etc.); the use of the method as an operational fishery-management tool would be investigated.
- Development of numerical techniques for nowcast/forecast of the mesoscale variability in the sea area surrounding the Maltese Islands, with the aim of producing short-term forecast maps of relevant oceanic features; in combination with remote sensing and in situ observations, the application of numerical models would be

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pursued to: (1) assess the seasonal occurrence and variability of fish abundance and type in the region, and (2) investigate the potential for operational forecasts of fish distributions and movements.

- Acquisition of physical oceanographic data by dedicated surveys and continuous observations to provide baseline information for numerical models, and improve the knowledge of the phenomenology of physical processes in the region (especially in the southern approaches to the Maltese Islands); measurements would be made from fixed points and CTD stations, and would include meteo and sea-level observations from coastal installations.

Available meteorological data series relevant to fishery ecology

Francis T. Gauci*

Abstract

The Maltese archipelago covers an area of 246 square kilometres in the centre of the Mediterranean. The interest in the weather has always been present among the inhabitants of the islands, and for various reasons.

It is desirable that meteorological data bases cover a considerable number of years, while being scientifically sound. Although various meteorological data sets have been assembled in Malta in the last hundred years or so, one may say with confidence that the meteorological data obtained by the meteorological office possess the required scientific attributes.

The MedSudMed Project could take advantage of existing data bases of meteorological parameters that may be relevant to the ecological aspects of fisheries, such as: air temperature; sea-surface temperature; surface wind parameters; sea wave parameters; cloud cover; hours of sunshine; solar radiation; and atmospheric pressure distribution.

The international meteorological community has been interested in the weather of the Mediterranean for a long time, and for various reasons. An abundant scientific literature (in terms of scientific papers, books and atlases) exists in this regard. Furthermore, groups of scientists from different fields have quite recently assembled and analysed meteorological data. MED-HYCOS and MEDEX are just two examples of projects being sponsored by the World Meteorological Organization to further such scientific research and study.

The exchange of data and expertise among the experts participating in the MedSudMed Project would certainly add substance to the studies being carried out.

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Review of environmental data available to the public on the Web

Vincenzo Giacalone*

Abstract

The present review was conducted within the framework of the Database and Information System Project. It concerns the screening of data and information available on the Web, the evaluation of their suitability, the accessibility and their possible relevance for the MedSudMed data base. It was, therefore, related only to the research, evaluation, and incorporation of available data from external sources.

The MedSudMed Co-ordination Committee, at its first meeting, stated the responsibility of the Data Base and Information System working group to design and develop the whole suite of software to be considered standard for all the participating project institutions. This is an important task, both because of the importance of the software component and because of the many possible applications in the Project's programme of work.

The overall objective is the establishment of a reliable and permanent regional information system to facilitate the exchange of information and its management, in all project domains, with a view to increasing the data integration, improving technology, as well as the quality of the information systems produced.

Conceptually, the long-term output is a large and multidisciplinary data bank exploited by a Decision Support System and by a GIS. This tool would enable the fisheries institutions of the four participating countries to carry out the continuous dynamic assessment and monitoring of the state of the stocks of fish and other living marine resources, as well as of the ecosystems in the central Mediterranean.

The requirements for processing power and technology, and the expertise, material, tools, resources, etc., are considerable, so many that the decision on the approach to be followed can only be taken after agreement is reached between all the interested participants.

This initiative has three objectives: (1) to present an activity that is being undertaken as a test; (2) to start collaboration with the other project groups, in order to enhance the possibility that the output may become the information vehicle and the processing tool to meet their needs; and (3) to meet with the regional experts to jointly verify the approach and set up a protocol to formalize the methodology.

The objective of this preliminary work was to find a series of web sites that contain environmental and biological data sets and to select those most relevant to the Project's needs. Biological data sets are not easily accessible to the public; therefore, results are focused on environmental data. A series of keywords were defined and helped in finding web sites that could be useful. The data sets are classified in order of importance in terms of available variables, and temporal and spatial resolution.

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Examples of maps that can be drawn using the extracted data are presented. These data come from the comprehensive oceanographic data set (COADS) and World Ocean Atlas–World Ocean Database (WOA–WOD). Differences between the data sets are exposed, as well as the advantages and the limitations of these data.

Application of remote-sensing technology to the study of the spatial distribution of demersal resources and the influence of environmental factors in the central Mediterranean

Charles Galdies*

Abstract

It is herein proposed to construct, validate and demonstrate a pilot remote-sensing application for a fishery management information system to assess and monitor the fishery resources and the ecosystems in the central Mediterranean. This could be partly achieved through state-of-the-art multidisciplinary and computational capabilities. This information system will mainly contribute to understanding how the environment affects the distribution of fish and influences recruitment.

A number of commercially important fish populations respond to changes in environmental conditions on inter-annual and longer time-scales. To relate physical variability to fluctuations in marine populations, one must understand how the ocean varies in space and time, particularly the primary patterns, sources, and mechanisms of inter-annual to decadal variability. Remote sensing can assist the MedSudMed Project to investigate changes in the central Mediterranean Sea on decadal scales from historical data, so as to determine physical mechanisms that lead to these changes. It would be relevant: (1) to develop indices of environmental conditions that can be applied to problems of fishery recruitment and population dynamics; and (2) to seek straightforward algorithms for the near-real-time estimation of important physical oceanic fields (e.g. water transport, mixed-layer depth, biologically effective upwelling) from readily available variables.

It has been demonstrated that the use of environmental data (such as sea-surface temperature[1], water colour, suspended solids, currents, ocean fronts, etc.) from satellite and airborne remote sensing can assist in the detection of migratory fish. Such an approach is being currently interpreted in the USA to provide intelligent tools and services to the fishing community, such as daily “road maps” to the fish. The strategy is to combine fishery oceanography and real-time satellite remote sensing to produce tactical and strategic fishery forecasts.

Therefore, a remote-sensing component within the MedSudMed Project could implement the following research:

- Synthesis and analysis of previously unanalysed environmental data sets acquired by remote sensing, using modern statistical and image-processing techniques to characterize and evaluate the regional marine fisheries habitat.

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[1] Demersal fish follow bait and comfortable water temperatures. For various reasons bait congregates at certain "structures", such as strong temperature gradients, which may indicate different water masses that do not easily mix. By locating and correlating the potential of bait to concentrate and the comfortable water temperature range for the target species with in situ data, one can trace the bait's movement and migration.

- Integration of efforts of remote sensing and state-of-the-art predictive modelling, including physical, biological and fishery data, to assess the interaction and use of remotely sensed data to study the effects of regional climatic variations on oceanographic processes important to fish populations.

Using its ground receiving station, Euro-Mediterranean Centre on Insular Coastal Dynamics (ICoD) is able to supply near-real-time processed data from raw data supplied by NOAA polar-orbiting satellites 12, 14, 15 and 16. These data, in conjunction with calibration software, would provide 1-km sea-surface temperature resolution for the central Mediterranean area. In addition to NOAA AVHRR data, data related to ocean colour is also received and processed. One key component of such data is chlorophyll-*a*, which is a strong indicator of the presence of nutrients in the ecosystem under study. Additional instrumentation, such as airborne digital imaging and multi-spectral scanning systems, would also complement data enhancement for detailed, high-resolution information, especially for inshore coastal waters. Data acquisition, image processing and analysis could be carried out by ICoD staff.

Modelling of environmental conditions relevant to assessment of fishery resources and ecosystems in the central Mediterranean

Slobodan Nickovic* and Anton Micallef

Abstract

In accordance with the objectives of the FAO–MedSudMed Project Assessment and Monitoring of the Fishery Resources and Ecosystems in the Strait of Sicily, we propose an environmental modelling study that specifically relates to the Project Framework task Environmental Effects on Fisheries, and more specifically to its Research on the Relationships between Fishery Resources and Biotic and Abiotic Parameters. Our proposal focuses on the physical environment of the region and possible interactions between fishery resources and abiotic parameters, by correlating model-simulated environmental conditions, nutrition processes and ocean-colour parameters.

Fishery management is mostly based on indirect estimation of fish productivity and incomplete knowledge of the dynamics of fish populations. There is a general agreement that fishery resources strongly depend on parameters such as ocean colour, sea-surface temperature, marine upwelling and salinity. By studying these conditions, indirect evidence can be obtained about fishery resources. For example, some tuna species feed in the warm seaward side of marine thermal fronts.

There are two basic mechanisms for bringing nutrients into the photosynthetic zone: (1) the marine eddies and related upwelling that brings nutrients from the sea bed to normally nutrient-limited surface waters; (2) the mineral dust produced by aeolian desert erosion and transported and deposited in the marine environment. Both processes stimulate plankton production (hence chlorophyll production) visible in satellite imagery as modified ocean colour. This primary plankton production is the first element in the fishery food web.

Use of the high-resolution sophisticated environmental models for predicting/simulating environmental parameters relevant to fisheries is a promising approach that may substantially complement marine observations. The multidisciplinary aspect of the fishery production requires use of mathematical models that integrate atmospheric, aerosol, and ocean environmental parameters and provide their feedback interactions. Such models produce 4-dimensional distribution of environmental conditions favourable for growth of fish populations. Use of model data could increase our understanding of fish life-cycles and improve assessments of fishery resources.

The recent NASA study (The Correlation between Atmospheric Dust Deposition to the Surface Ocean and SeaWiFS Ocean Color: A Global Satellite-based Analysis) is an example of increased scientific interest in linking environmental conditions with fish productivity. In this study, dust-deposition climatology was simulated by a global dust model and correlated with satellite-derived ocean colour data. The study clearly identified areas with a high correlation between received nutrients from wind-blown dust and ocean productivity.

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We suggest evaluating the regional model climatology of parameters responsible for the following major nutrition mechanisms: (1) ocean circulation (upwelling); and (2) dust deposition. They will be correlated with the satellite ocean-colour data in order to identify the central Mediterranean areas favourable to the growth of fish populations. The study will produce evidence with respect to spatial and temporal (seasonal) distribution of potentially high fish productivity.

By anticipating results from the proposed climatology study, design and development of a prototype modelling system for routine prediction of environmental conditions relevant to the assessment of the time and locations of fish populations in the central Mediterranean will be assured.

Knowledge and spatial management tools for the environmental sciences

Matthew Gatt*, Carol Agius and Matthew Camilleri

Abstract

Under the MedSudMed Project the broad range of research topics needs to be facilitated through the use of appropriate data-management tools. This is achieved by using best practices to promote the synthesis of knowledge amongst the diverse participants in the region.

The use of GIS in fisheries management has developed significantly in the past decade. The technology is being applied as a decision support tool in a broad range of issues related to marine ecosystems, natural phenomena and fisheries.

Structured approaches to knowledge management within corporate environments are a more recent development. These approaches are rapidly maturing into frameworks that facilitate the synthesis of knowledge across "loosely coupled" entities. Such frameworks are particularly useful in building national and regional cooperation and support frameworks, bridging technology with the traditional approaches of personal networking and focal points.

The MedSudMed Project would benefit from an approach to these issues that is as independent as possible of specific technical platforms and can be applied to a broad range of similar projects.

To facilitate the broader deployment of information amongst the participants, the proposed development will focus on coherent datasets and access to information using standard widely available tools. The solution would provide an Internet-based infrastructure for sharing and transacting knowledge, information and data with particular focus on GIS and scientific datasets.

In particular the project will address:

- The data structures for the project based on a hierarchical approach to the ecosystem components
- Meta-data dictionary for facilitating use and understanding of data sets
- Standard data specifications and adaptive gridding of abstracted data sets
- Basic processing tool for abstracted datasets.

The knowledge management infrastructure will include the following key building blocks:

- A spatially enabled information portal
- Federated search facilities

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- Taxonomy, classification and indexing of information sources
- Document/information management systems
- Collaborative application environments and/or workspaces
- Simultaneous collaboration.

During the present expert consultation the general approach outlined above will be illustrated in further detail through the use of example scenarios developed by the Malta Centre for Fisheries Sciences.

The "Ressources" application

Alexis Bensch*, Othman Jarboui

Abstract

"Ressource" is a computerized application for the management and spatial analysis of fishing-survey data. Information is structured according to the relational data model. A first module manages the data collected by the scientific surveys. Data are edited through a user-friendly interface, which includes some quality check. A second module assists the scientist in building up selections of sampling stations and calculates abundance indexes. Selection criteria and abundance indexes calculated are managed by the system. The result of a selection is automatically exportable to a geographic information system (GIS) software, where maps are built to display the abundance indexes calculated on the stations of the selection. The system is able to detect changes in the selection criteria and update the related maps accordingly. The scientist may proceed to the spatial analysis of the abundance indexes and create new maps which will be automatically stored in the map library of the selection.

This application has been used for demersal trawl-survey data, but should easily cope with pelagic survey data. The application is available at no cost but requires Microsoft ACCESS and ESRI Arcview commercial packages. Source code (Visual Basic for Applications and Avenue) is opened and fully documented in order to facilitate personalization or development of new modules by users. User interface is in French.

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Potential biological and environmental influences on the *Octopus vulgaris* population of the Gulf of Gabès (south-eastern Tunisian coast)

Soufia Ezzeddine* and Amor El Abed

Abstract

Octopus fishing is abundant along the Tunisian coasts especially in the Gulf of Gabès, which accounts for 83% of the national landings. In spite of the Tunisian regulation controlling the octopus fishing, the catch is variable. The potential causes of such variability are presented and qualitatively discussed.

1. Introduction

The most exploited cephalopod species along the Tunisian coast are the common cuttlefish (*Sepia officinalis*), the musky octopus (*Eledone moschata*), the broadtail squid (*Illex coindetii*) and the common octopus (*Octopus vulgaris*). Of these, the common octopus is the most important target species, especially in the Gulf of Gabès (Figure 1), where the landings represent 83% of the national production destined for local consumption and mainly for exportation. Actually, the Gulf of Gabès presents the best environmental conditions for the expansion of the octopus stock and the use of static and traditional gears which ensure the selective capture of octopus. The artisanal fishing provides 90% of the octopus landings in this region. The increase in fishing effort on the southern octopus stock raised the coastal landings from 2,600 tons in 1975 to 12,000 tons in 1988; nevertheless, production underwent many fluctuations between 1975 and 2000.

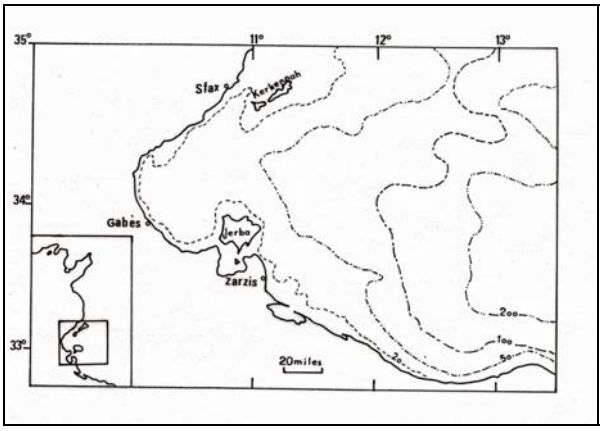

Figure 1. Geographic situation of the Gulf of Gabès

Octopus vulgaris fishery regulations were established in 1987 and were amended in 1992 and in 1994. These regulations provide that fishing any octopus weighing less than 1 kg is forbidden from 16 May to 15 October, but allow the possibility of delaying or advancing,

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respectively, the opening or the closing dates. The decision was taken on the basis of the results of biological sampling both before the opening campaign and during the fishing season for the closing time. These regulations concern both trawling and artisanal fishing. However, in spite of this legal control, the annual production has undergone annual fluctuations, with a falling trend since 1990 (Figure 2).

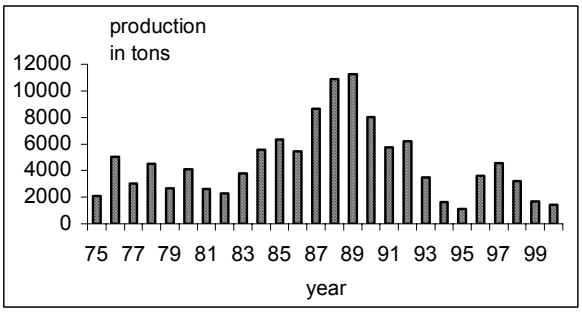

Figure 2. *Octopus vulgaris*: coastal landings in the Gulf of Gabès (from 1977 to 2000)

Fluctuations in landings might reflect modifications in the pattern of fishing (e.g. changes in the distribution of fishing in time and space, dispersion or concentration, and variation in the effectiveness of a unit of fishing effort) and in the interactions between the octopus and the bio-ecological and environmental factors, in addition to the effects of human activities. Since all these factors posed a problem in the rational management of the stock, we have tried to review here the different factors that might explain the variation in the landings and prevent an accurate stock assessment.

2. Materials and methods

The data used in the present work were from biological and dynamic studies of octopus in the Gulf of Gabès and from surveys conducted in the region. Data from the literature dealing with the physical and chemical characteristics of the central Mediterranean were also considered here.

For each factor, whether it was inherent in the biological parameters of the octopus or linked to the environmental conditions, we tried to draw up an evaluation sheet of the potential effects to explain the octopus catch variability. Three parameters were considered particularly as factors affecting the octopus fishing:

- the bio-ecological characteristics
- the behaviour of the octopus with respect to the environment
- the environmental effects, excluding the specifically oriented effects of human activities (i.e. those not directly linked to the fishery for the species investigated).

3. Results

3.1 Bio-ecological effects

The octopus has a biological predisposition to govern its own stock. The reaction of the stock to biological variability is fast and depends on the fishing method. These changes affect a number of biological parameters which are discussed in the present paper.

Growth and life-span

In the Gulf of Gabès, the octopus grows quickly and at a nearly constant rate, particularly during the first months of its life. In fact, according to the results of Zguidi (2002), there are two cohorts in the octopus population of the Gulf: one from the spring spawning, characterized by a high growth rate and a short life-span; the second is from the summer spawning, distinguished by a lower growth rate and a longer life-span. However, the global formula established for octopus growth, with respect to the stock in the Gulf of Gabes, is an exponential equation:

$$Lt= 29.6*[1–exp(–0.560*t+0.225)]$$

where Lt is mantle length in centimetres; t is in years.

Like most cephalopods, the octopus of the Gulf of Gabès has a very short life-span, estimated between 13 and 20 months, depending on the laying period, and rarely exceeds 2 years. Thus, the biggest animals sampled in Tunisian waters (weighting 10 kg) were not necessarily older than 3 years, but they likely found adequate food supplies which contributed to their rapid growth (Ezzeddine-Najaï 1992).

Short life-span and high growth rate afford the common octopus stock a high turnover rate and therefore ensure a potentially rapid renewal of the stock. This rate is estimated at 16% of the mean biomass, according to a stock assessment of the species in the Gulf of Gabès which revealed an overexploited stock (Zguidi 2002). Besides, on account of the same biological effects, the stock is sometimes subject to large variation with the possibility of a population explosion or collapse. These fluctuations are often difficult to forecast, because it is difficult to monitor changes in stock size over a very short life-span (1.5 years). Such an event was recorded for the octopus stock in the Gulf of Gabès between 1977 and 2000 (Figure 2) and elsewhere in the coastal water of the Gambia and of neighbouring Senegal between 1986 and 1990 (Caverivière 1994).

Reproduction

In the female, fertilization of the eggs is internal; the introduction of the male's hectocotyle into the female's mantle cavity ensures that the fertilization takes place inside the glands of the oviduct where the spermatozoa are stocked (Mangold and Boletzky 1973). In the Gulf of Gabès, 50% of the female population reaches sexual maturity during the second year of life when the mean size of the mantle length reaches 14.5 cm. The first year of their life is devoted to increasing the body weight, hence the stock weight. Moreover, this method of reproduction constitutes a biological protection of the stock against environmental risks.

Spawning and fecundity

Sexual maturity is reached at an average weight of 1200–1450 g (Ezzeddine-Najaï 1992; Zguidi 2002). These results agree with those reported for the species inhabiting other geographical areas (Mangold-Wirz 1963; Guerra 1979; Hatanaka 1979; Caverivière 1990).

In the Gulf of Gabès, females of the common octopus have a prolonged spawning season (from February to September) with a peak between March and July, whereas the males are mature all the year round. The breeding is preceded by an inshore migration in autumn, the males preceding the females (Ezzeddine-Najaï 1992). This migration has a genetic and probably a trophic origin. Along the coasts, the animals find enough light and feeding (crabs, shrimps and shellfishes) for gonad growth. In early spring, a large number of adult females isolate themselves in shelters for spawning.

The potential fecundity expressed as the number of ova in one ovary is equally important; the values estimated for Tunisian species are between 127,607 and 1,326,597, but the number is not related to the size of the animal (Zguidi 2002). These results agree with those obtained for other Mediterranean populations, such as those in the Catalan sea, where the number of eggs laid by a female varies from 100,000 to roughly 500,000 (Mangold 1983). The large number of eggs emphasizes the importance of fertility in the common octopus compared to other octopus species.

The above-mentioned biological characters (extended spawning season, method of reproduction, spawning migration, high fertility) ensure a high yearly recruitment to the stock. On the other hand, when the octopus moves inshore, a large number of maturing animals are subject, before breeding and spawning, to precocious capture by trawlers which cut off their way inshore.

3.2 Behavioural effects

The natural behaviour of this species was observed and described in the laboratory and in the field.

Egg care

The female always attaches its egg strings to the substrate on rocky shores, in a hole or any sheltered place generally inaccessible to trawl nets. During the incubation period, the female ventilates and protects the eggs until they hatch, starves and usually becomes senile and dies. However, in spite of the high level of maternal care, several eggs are often eaten by predators inhabiting the same areas as the octopus. These losses have a negative effect on stock recruitment.

Planktonic stage

Hatchlings live for some time in the plankton (Figure 3) and then sink to the bottom. During the planktonic phase, they are transported by the water currents which ensure them a large distribution throughout the sea. Nevertheless, the juveniles are very vulnerable to environmental risks and the mortality rate is significant during this phase. In rearing experiments, the survival rate, from hatching to settling, was only 9% (Itami and al. 1963); but in natural conditions, this rate probably exceeds 90% (Mangold 1983).

Figure 3. Newly hatched 24-h-old *O. vulgaris* (INSTM Museum, Salammbô)

Way of life

Other very particular behavioural characteristics allow the species to protect itself from environmental dangers.

According to the aggregation indices of the spatial distribution of the species (Guerra 1981), the octopus is normally solitary and territorial, especially in the spawning season. It digs into soft substrata to rest quietly during the daytime. Juveniles and females bury themselves in sandy and muddy sediment to shelter against predator attack (Boletzky 1996). The bottom of the Gulf of Gabès is muddy or sandy, covered over a large area by seagrass and inhabited by several species, among which, the common octopus finds its favourite prey: crustacea (Decapod sub-orders Macrura, Brachiura, Anomura), molluscs (classes Gasteropoda, Cephalopoda) and fishes (order Teleostei) (Ezzeddine-Najaï 1992; Zguidi 2002) (Figure 4).

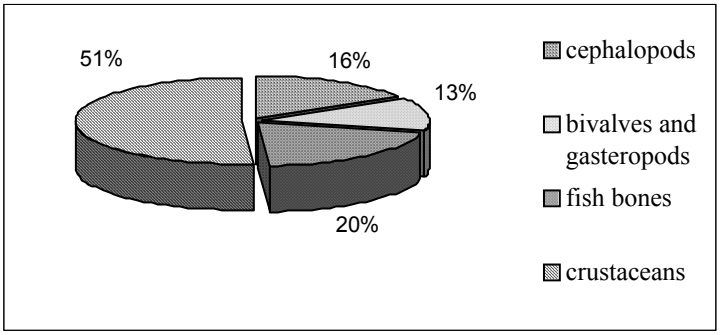

Figure 4. *O. vulgaris*: frequency of occurrence of various prey items in the diet

Unfortunately, the recent degradation of the bottom in the Gulf of Gabès, due to excessive bottom trawling, has affected the environment and contributed to a decrease in the extent of the octopus population and consequently to a drop in the catches in the Gulf.

General behaviour

The common octopus changes its appearance in response to some environmental and physiological events (ejecting, hunting, reacting to disturbance etc.) described by Packard and Sanders (1971) and Mather and Mather (1994). In addition to anti-predator behaviour (modification of skin colour and texture), the octopus is able to hide itself behind a cloud of ink ejected from the funnel.

These highly developed kinds of instinctive behaviour (burying, mimesis, maternal instinct) help to protect the octopus from drastic overfishing. In contrast, the interspecific interactions between the octopus and others species inhabiting the same biotope remain a continual danger for the common octopus. Among these competitive species, we especially mention the grouper, the sea bream and the moray.

3.3. Environmental effects

Biotic and abiotic effects

Several factors characterize the Gulf of Gabès and influence the life of the octopus. Among these factors, we note the large area of the continental shelf, which is especially marked by a gradual slope and by the many channels around the Kerkennah Islands. Thus, the line of the 50-m isobath to the north of Gabès is 110 km from the coast, and the 100-m and 200-m isobaths are 175 km and 250 km from the shore, respectively. The tides here have the biggest amplitude in the Mediterranean, with a maximum of 2.4 m. The Atlantic water flows through the Strait of Sicily and then turns southwards. The seasonal variability of this cyclonic circulation affects the water circulation in the Gulf of Gabès (Poizat 1970). The distribution of the octopus in this area would be related to the fluctuations in this cyclonic water circulation which is rich in suspended sediments (Brahim *et al*. 1994), in addition to the hydrographic parameters (high temperature and salinity). The biodiversity is equally rich and characterized by Neptune grass (*Posidonia oceanica*) and seaweed beds covering a large area. All these characteristics of the Gulf of Gabès favour the expansion of the octopus, but also the use of specific fixed fishing gears to capture the species.

Effects of human activities

The geomorphological and hydrographical features of the Gulf of Gabès have favoured the development of a traditional activity based on the use of "static" gears, such as pots, traps and bored stones, to catch the octopus (Najaï 1981). In the same way, a very important industrial fishery, mainly based on bottom trawling, has been developed. Excessive fishing pressure is exerted on the octopus stock, not only during fishing season but also clandestinely outside it, in spite of the restriction measures. A large number of juveniles have been captured in recent years off-season, inducing a quantitative and qualitative decrease in the octopus landings.

In other words, human activities in the Gulf of Gabès have contributed to the variability of the coastal biodiversity, affecting the flora and fauna and then ecosystem stability. The loss of

the seaweed beds has altered sedimentation, with an important impact on the nature of the sea bed. This alteration could have induced a temporary predominance of some animal species that would in turn be reduced. So, in 1980, the overfishing of species of grouper and sea bream caused a drop in the landings in the Gulf of Gabès. Their reduction would have permitted the temporary proliferation of their preferred prey, the octopus, which, having a high turnover rate, would have resisted aggression initially. Subsequently, becoming in turn vulnerable to the destabilization of the ecosystem, the octopus landings would have decreased after 1988, as is illustrated in Figure 2.

4. Discussions and conclusions

The stock of *Octopus vulgaris* is affected by several factors which are related to biological parameters and environmental conditions, including human activities and which make it difficult to forecast the stock level.

A study of *Octopus vulgaris* along the north-western coast of Africa (Demarcq and Faure 2000), indicated that a demographic explosion occurs when the environmental conditions, particularly upwelling, help larval survival. Similarly, Faure *et al*. (2000) noted the importance of retention by the upwelling, as an environmental index, in areas of *O. vulgaris* recruitment over the Arguin Bank off Mauritania.

In the Gulf of Gabès, there is no upwelling to have comparable effects on the interannual variability in the catches. However, the incoming water from the Atlantic is divided into two currents in the western Mediterranean; one moves northwards and the other flows towards the eastern Mediterranean and reaches the Gulf of Gabès, feeding a cyclonic current within the Gulf (Brahim *et al.* 1994). This eastern stream has a pronounced seasonal variability which, in turn, affects the water circulation in the Gulf of Gabès. The permanent cyclonic circulation in the Gulf could have an effect on the variability of the recruitment of the octopus and eventually on the biomass, depending on the importance of the flow, which would partially explain the fluctuations in the catches. To verify the accuracy of these effects, we need a regular series of annual data which would allow study of the relationship between the recruitment to the octopus stock and the hydrographic parameters of the Gulf (wind, tides, water circulation, sediment flux, particulates dynamics etc.). Such data series should include those from remote-sensing satellites. Meanwhile, annual monitoring surveys are conducted in Tunisia in order to preserve the stock, although the need to determine the independence of the octopus stock in the southern part of the Gulf remains. To meet this need, we propose a tagging project in collaboration with the bordering countries.

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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).

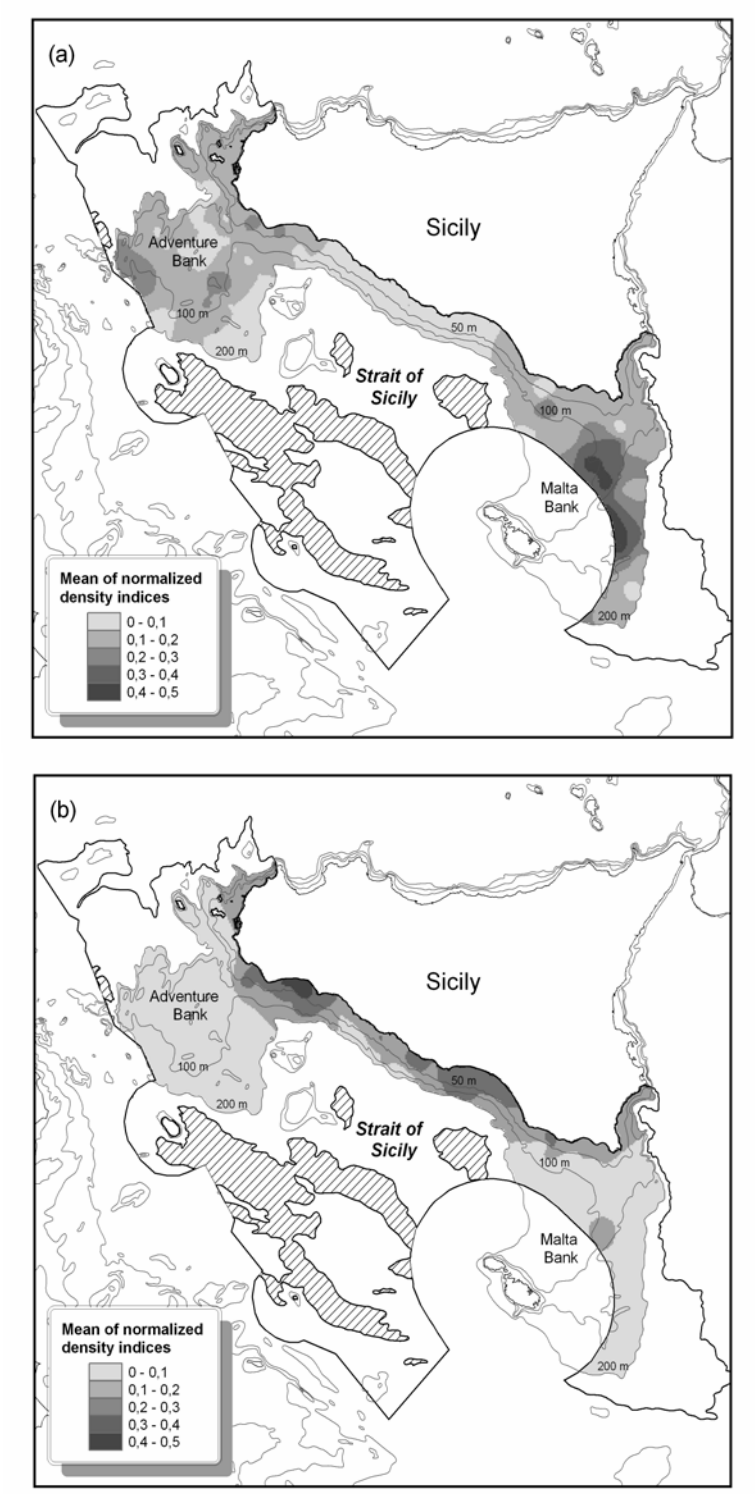

Figure 1. Spawning (top panel - a) and nursery (bottom panel - b) areas of *Mullus barbatus* (from Garofalo *et al.* 2002a)

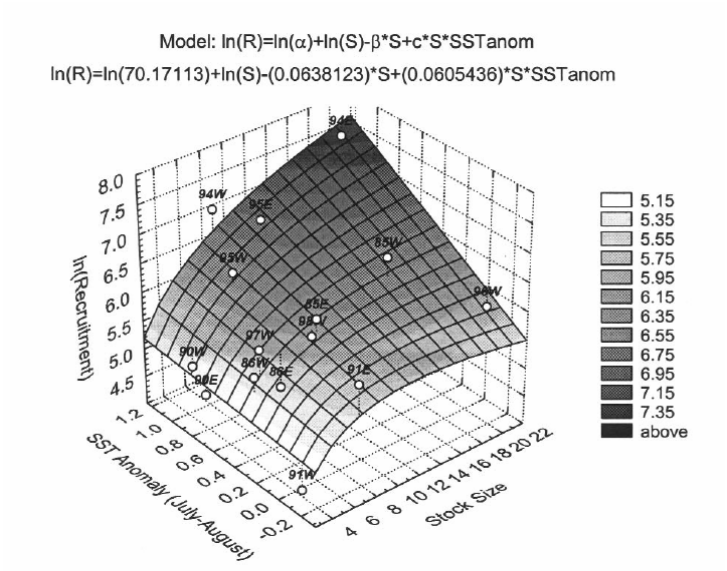

Figure 2. *Mullus barbatus.* Stock–recruitment relationship and environmental factors (from Levi *et al.* 2003b).

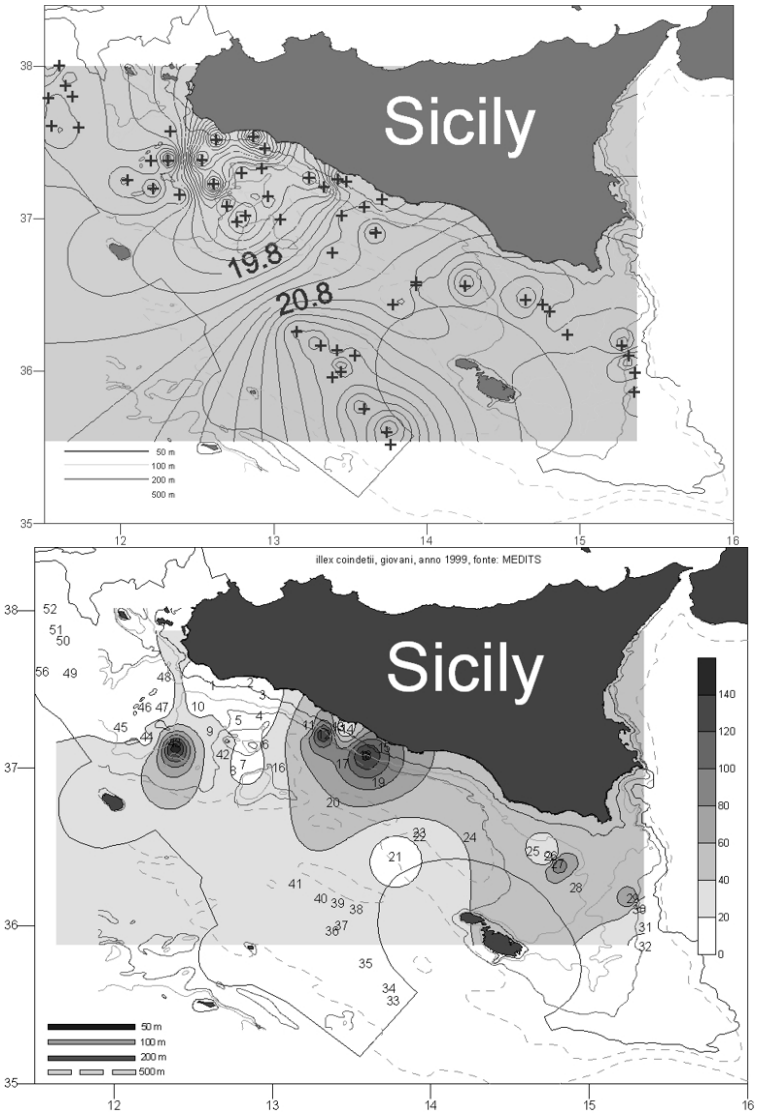

Figure 3. *Illex coindetii*. Frontal system, derived from sea-surface temperature (top panel) and distribution of nursery areas (bottom panel) in the Strait of Sicily (from Jereb *et al.* 2001).

***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).

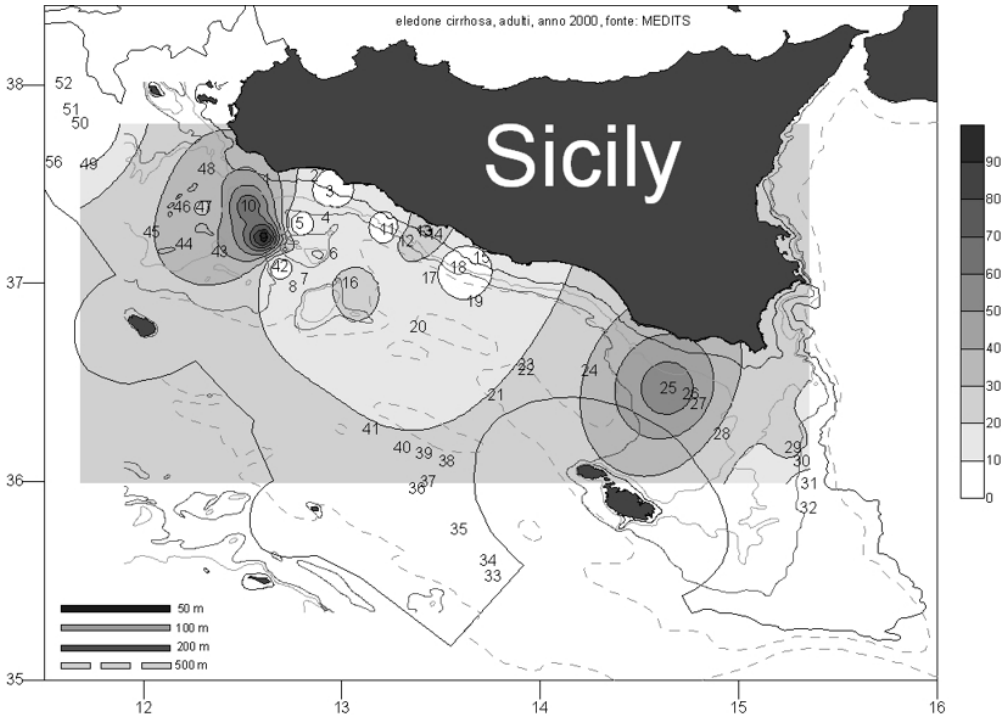

Figure 4. *Eledone cirrhosa.* Distribution of adults (from Jereb *et al.* 2001).

***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).

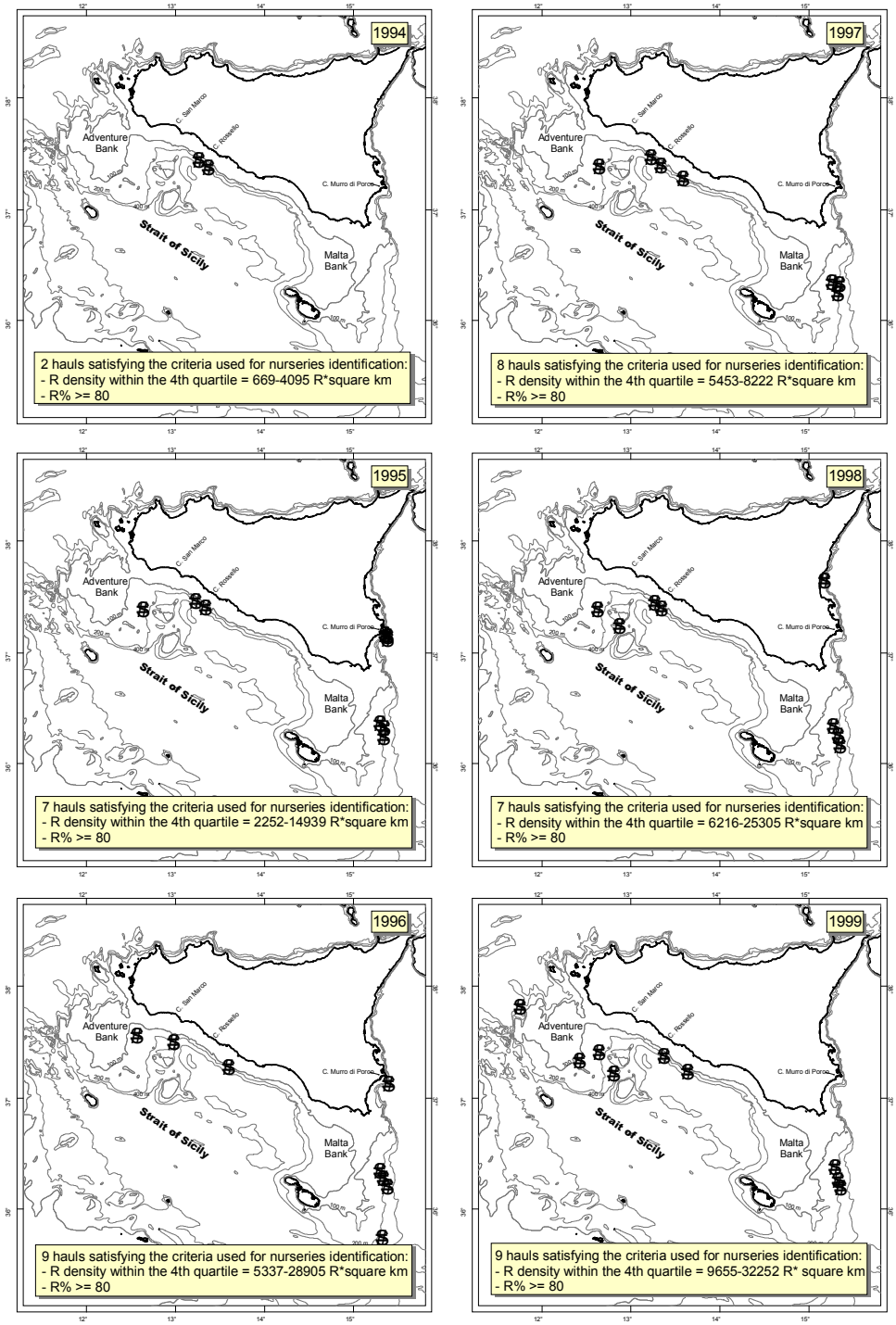

Figure 5. *Parapenaeus longirostris*. Occurrence of recruits, showed by solid dots, in the Strait of Sicily (from Fiorentino *et al.* 2002)

***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.

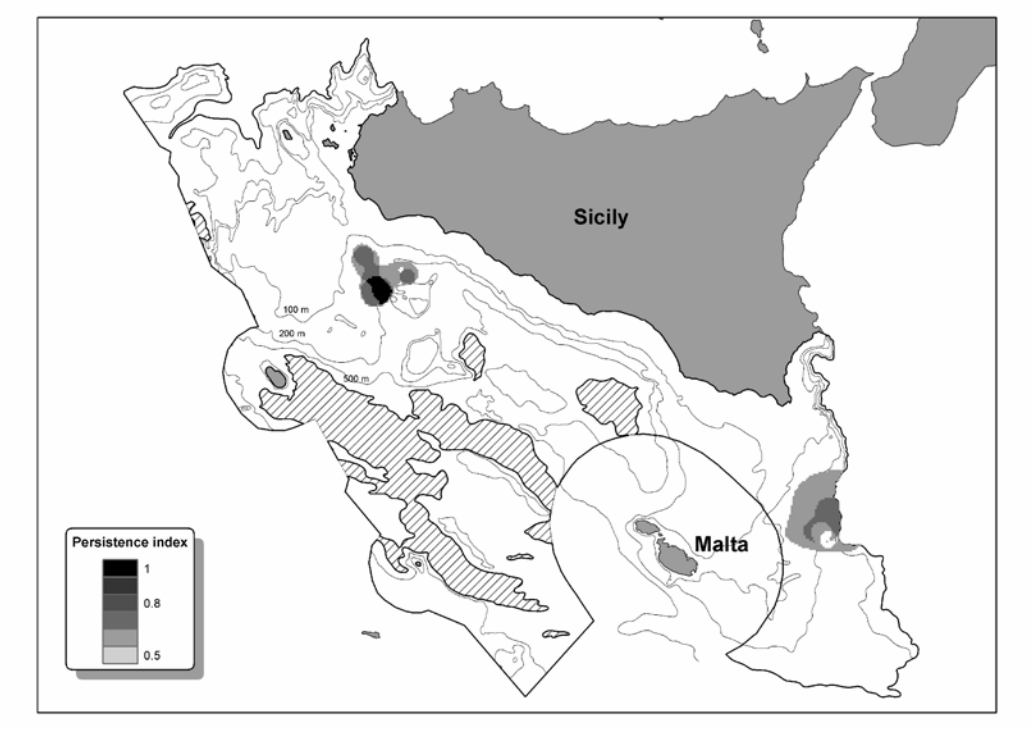

Figure 6. *Merluccius merluccius*. Stable nurseries in the Strait of Sicily (from Fiorentino *et al.* 2003a).

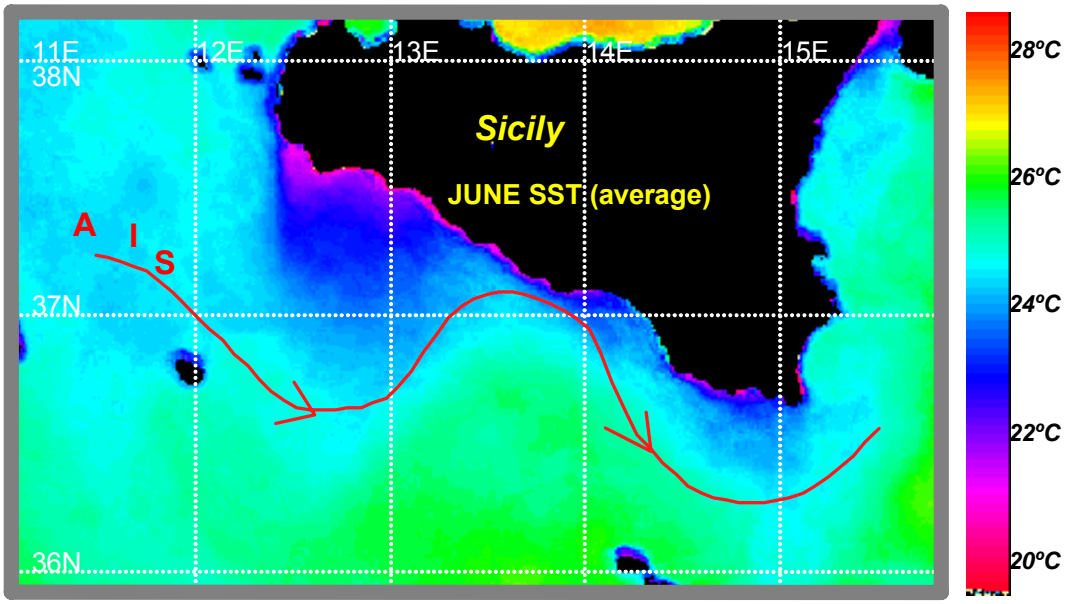

Figure 7. Sea-surface temperature and the Atlantic–Ionian stream (*AIS*) (from García La Fuente *et al.* 2002)

***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).

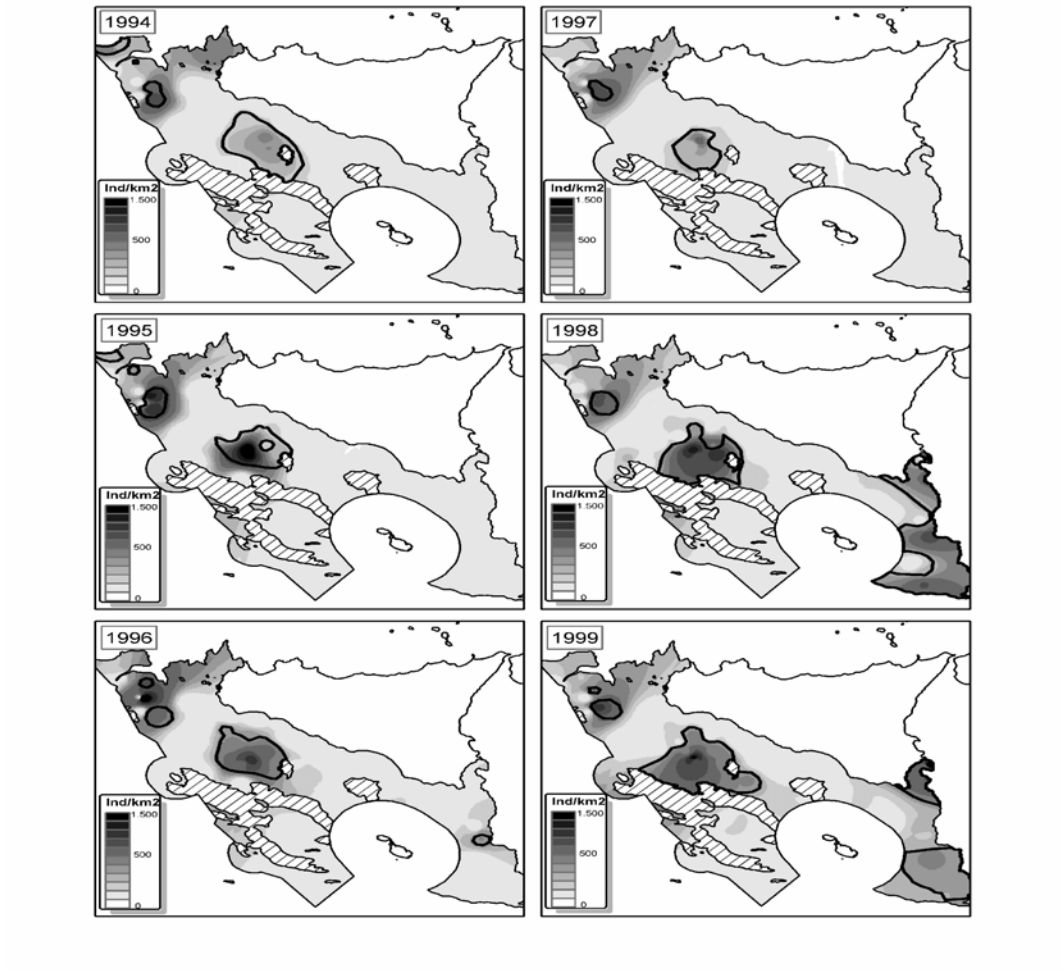

Figure 8. *Phycis blennoides.* Nurseries in the Strait of Sicily (from Fiorentino *et al.* 2003a).

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).

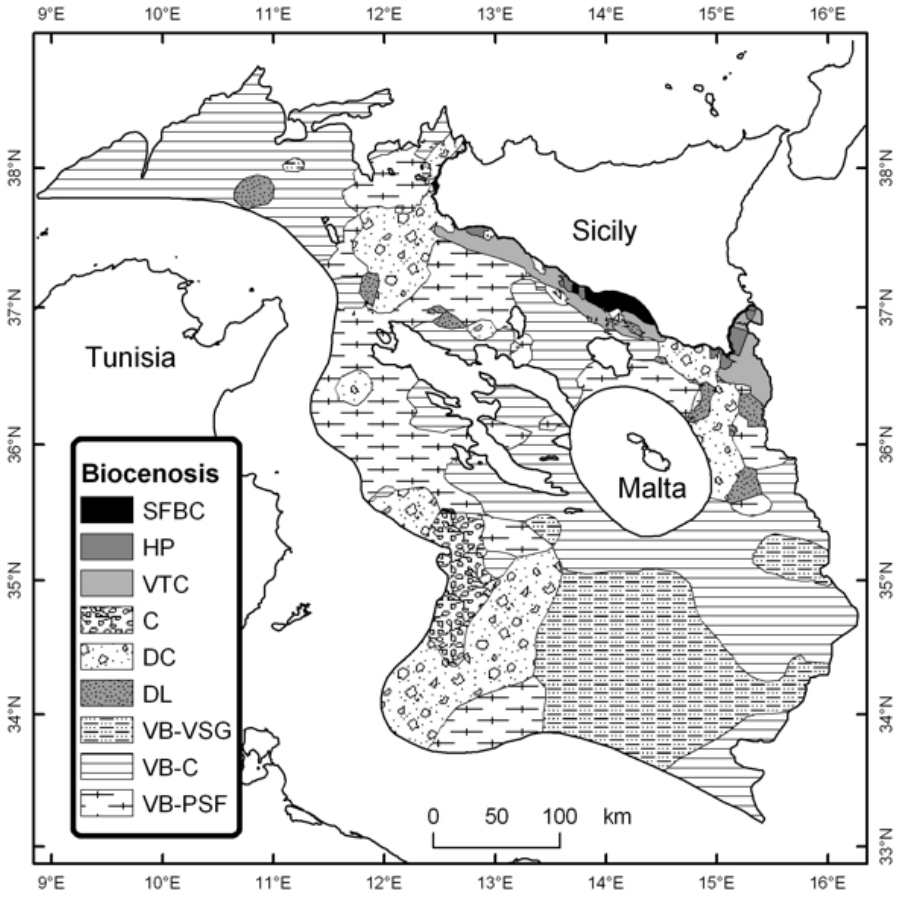

Figure 9. Map of the benthic biocoenoses in the Strait of Sicily (from Garofalo *et al.* 2002b).

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).

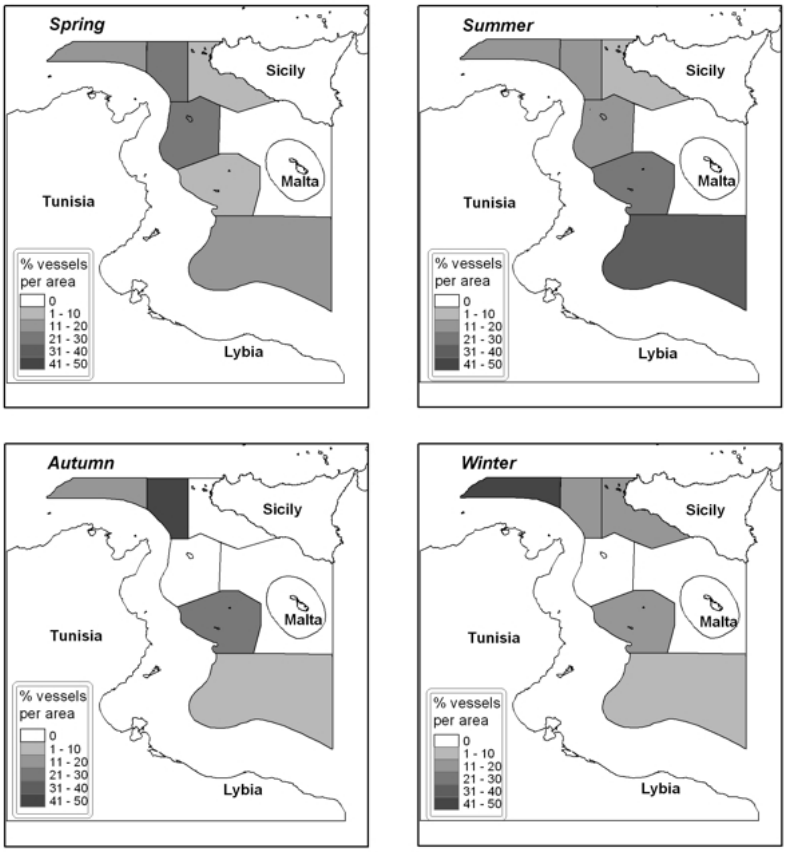

Figure 10. Seasonal distribution of the fishing pressure (unpublished data)

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).

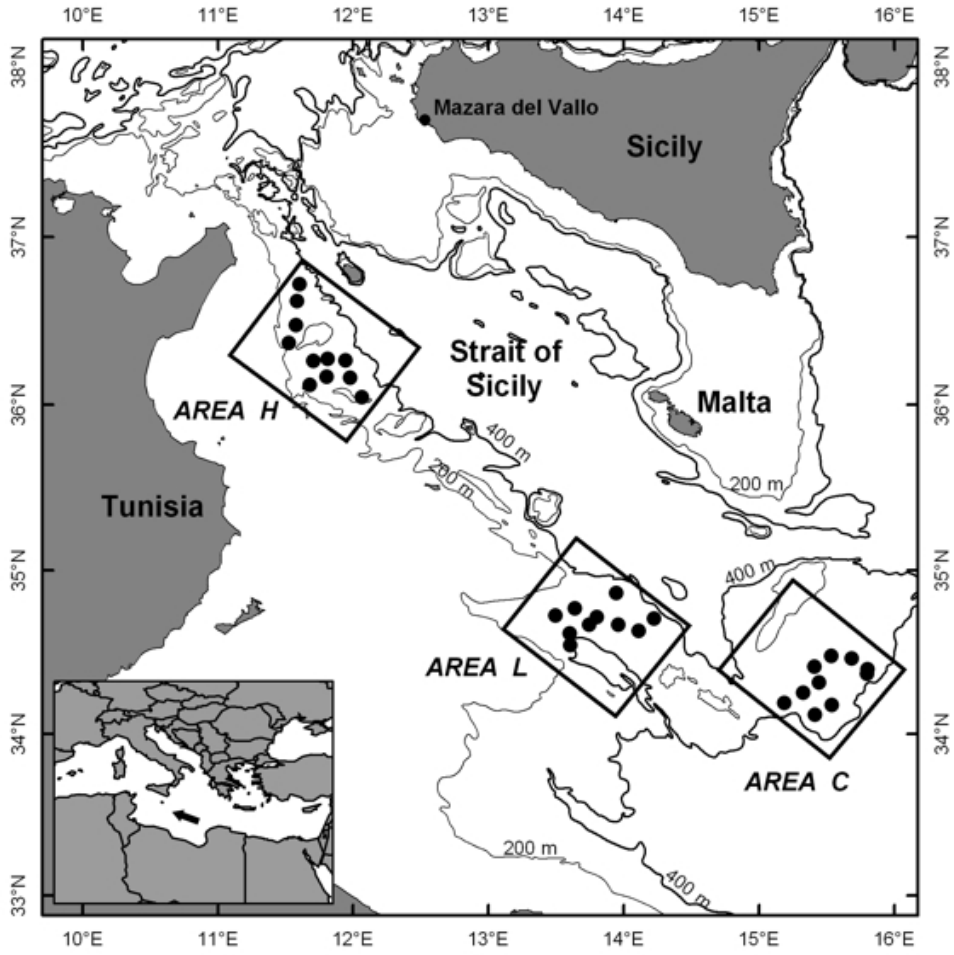

Figure 11. Areas with different level of fishing pressure (*H* high; *L* low; *C* control) (from Gristina *et al.* 2003)

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.

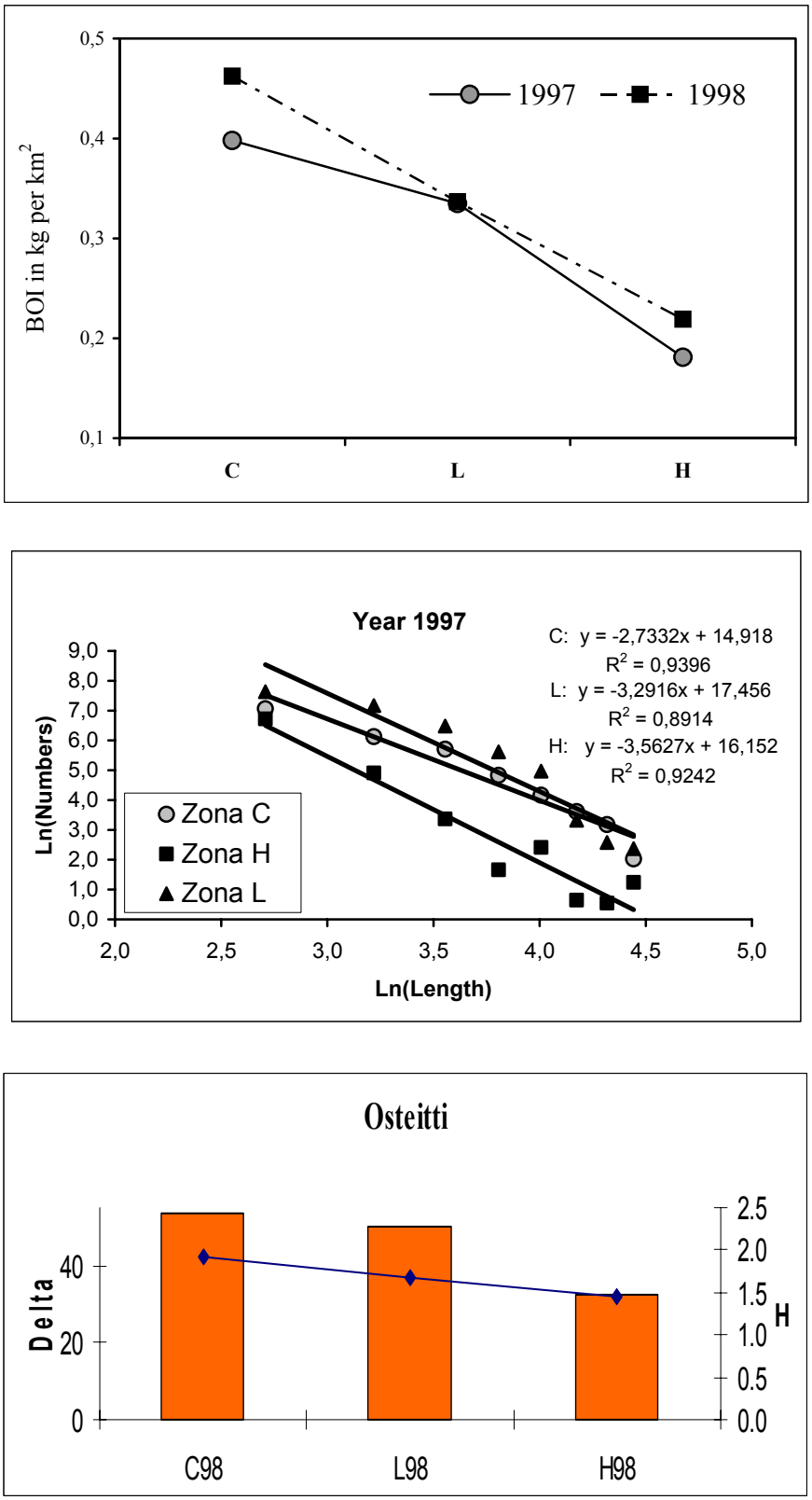

Figure 12. Multispecific indices from areas with different level of fishing pressure (H high; L low; C control) (from Fiorentino *et al.* 2003b; Gristina *et al.* 2000, 2003)

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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Overview of the available biological information on demersal resources of the Strait of Sicily

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Abstract

Biological information on the demersal resources of the Strait of Sicily collected during the trawl surveys carried out routinely in the Strait since 1985 is presented. Data concern bottoms of 10 m down to 800 m depth. A total of 143 species or higher taxa, whose density indices (DI; N/km^2) and biomass indices (BI, kg/km^2) are available for the whole study area, are recorded in the IRMA–CNR data base. More detailed information (i.e. size composition, sex ratio, gonad maturity and demographic parameters) are available, although with temporal gaps, for 18 target species: *Helicolenus dactylopterus, Lepidorhombus boscii, Merluccius merluccius*, *Mullus barbatus, M. surmuletus, Pagellus erythrinus, Peristedion cataphractum, Phycis blennoides, Galeus melastomus, Mustelus mustelus, Raja clavata, Scyliorhinus canicula, Aristaeomorpha foliacea, Nephrops norvegicus, Parapenaeus longirostris, Eledone cirrhosa, E. moschata, Illex coindetii.*

1. Introduction

Most of the biological information on groundfish gathered by IRMA–CNR in the Strait of Sicily was obtained within the framework of two main programmes of assessment of demersal resources: the GRUND program, started in 1985 and funded by the Italian government (Relini 2000) and the international programme MEDITS, started in 1994 and supported also by the Europen Union (Bertrand *et al.* 2002).

The aim of this review is to summarize the available information at IRMA–CNR for the main target species in the Strait of Sicily. This information concerns both the average abundance per unit surface (km^2) in kilograms and number, as well as the main length characteristics (range and median length) and most relevant demographic features (growth, maturity and mortality).

2. Material and methods

Data were collected during depth-stratified bottom trawl surveys. The explored bottoms, between 10 and 800 m, were divided into five depth strata (10–50; 51–100; 101–200; 201–500 and 501–800). Most of the campaigns were carried out in spring and autumn, although other seasons were available for some years. Samples were collected with the professional stern trawler "S. Anna" and two standard gears, with a fine mesh in the cod-end (20–30 mm opening) (Levi *et al.* 1998).

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The surveyed area, shown in Figure 1, concerns the Italian side of the mid-line of the Strait of Sicily for the main of campaigns (Area A). Information was also collected in the offshore water (Area B) during the GRUND surveys of 1997, 1998, 2000 and 2001, whereas in 2000, 2001 and 2002, data inside the Maltese Exclusive Fishing Zone were collected together with Maltese scientists, within the framework of the MEDITS programme.

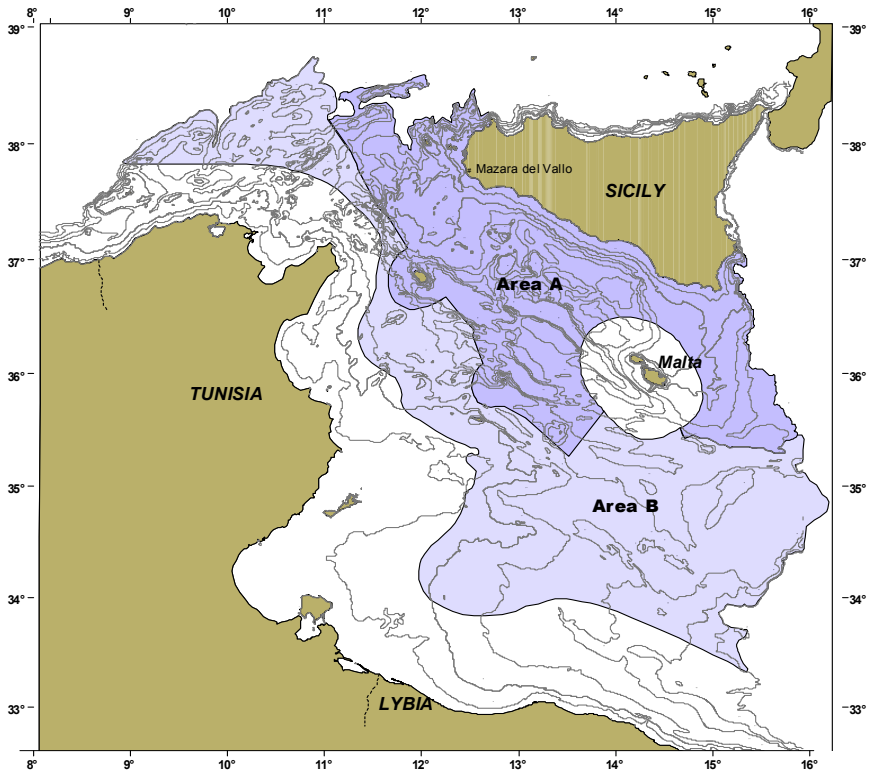

Figure 1. Strait of Sicily. Area investigated within the framework of the GRUND and the MEDITS programmes. The area A, bound by the mid-line is distinguished from the offshore water (area B).

Data were processed to obtain abundance indices in terms of number (Density Index, DI, kg/km^2) and biomass (Biomass Index; BI, kg/km^2) per square kilometre of the whole catch and biological information on the target species (length–frequency distributions, sex ratio, maturity stage, age composition, growth, mortality, etc.). Abundance indices are routinely estimated by stratum, but those referring to the shelf (10–200 m; i.e. 1st, 2nd and 3rd stratum combined, here defined as shelf index) and slope (201–800 m; i.e. 4th and 5th stratum combined, here defined as slope index) are reported herein for the sake of simplicity. Given the aim of the present contribution, the abundace data reported here were provided by the trawl surveys carried out from 1994 to 2002 during the MEDITS programme. A preliminary trend analysis in the abundance was performed after $\log_e$ transformation of the average density indexes (DI, N/km^2); the level of significance for the straight-line regression was set at $P \leq 0.05$.

The life-cycle parameters, and particularly, growth parameters, by sex and by females and males combined, were generally derived both from length-distribution analysis and otolith readings, based on the classic von Bertalanffy growth model. For some cartilaginous fish, the vertebrae were employed for ageing (see Cannizzaro *et al.* 1995). Length–weight relationships were calculated by the usual allometric model. Sex ratio was expressed as the

proportion of females in the total number of individuals sexed, for the whole population and by size-class. Size at maturity was estimated by using the classic ogive. The spawning periods were identified by the analysis of maturity stage and of the gonad-somatic index throughout a year. The recruitment period was established by considering the massive occurrence of small-sized specimens in the samples provided by trawl surveys. Total mortality rates were mainly estimated by the means of the length-converted catch curve, whereas the natural mortalities were assessed by empirical methods, depending on the characteristics of each species. More details can be found in SAMED (2002), IRMA (2003), Fiorentino *et al.* (2003), and in the paper by Fiorentino *et al.* in the present report.

3. Available information

A total of 143 species or higher taxa, whose abundance and biomass indices are available over the study area, is recorded in the IRMA–CNR data base (IRMA 2003). More-detailed biological information, however, is available for a restricted number of species chosen according to both their commercial importance in the Strait of Sicily and their consistent presence in the IRMA–CNR data base for a long time. At the moment, there are 18 target species distributed among the most relevant taxa, as follows:

- **Osteicthyes:** *Helicolenus dactylopterus, Lepidorhombus boscii, Merluccius merluccius*, *Mullus barbatus, M. surmuletus, Pagellus erythrinus, Peristedion cataphractum, Phycis blennoides*
- **Chondrichthyes:** *Galeus melastomus, Mustelus mustelus, Raja clavata, Scyliorhinus canicula*
- **Crustacea (Decapoda):** *Aristaeomorpha foliacea, Nephrops norvegicus, Parapenaeus longirostris*
- **Cephalopoda:** *Eledone cirrhosa, E. moschata, Illex coindetii.*

A synoptic overview of the biomass indices and length features are presented in Table 1, whereas a synthetic, though not exhaustive, inventory of the existing information on their life-history characteristics is presented in Table 2.

Table 1. Synoptic overview of the biomass indices (BI) for the shelf (10–200 m) and slope (201–800 m) and length features for the target demersal species of the Strait of Sicily. Lengths refer to total, carapace and dorsal mantle length for fish, crustaceans and cephalopods, respectively.

Species	Biomass index (BI, kg/km^2)				Length range (mm)	Median length (mm)	Remarks
	Shelf		Slope				
	BI value	year	BI value	year			
Helicolenus dactylopterus	–	–	2.6 17	2001 2002	20–330	120	Occurs both on the shelf and on the slope, but the bulk of the catch was taken on the slope; high discard rate among the long-distance trawlers.
Lepidorhombus boscii	–	–	0.7 1.8	1997 1995	70–380	160	Almost exclusively observed on the slope, always in low quantity
Merluccius merluccius	20.3 37.8	1998 1994	14.5 27.6	1996 1994	40–760	100	Fished in a wide bathymetric depth range; almost disappeared below 500 m; high discard rate for specimens below 15 cm in length; no evident trend
Mullus barbatus	4.5 12.5	1994 1996	0.1 0.2	1997 1998	55–250	140–150	Caught nowadays almost exclusively on the shelf; low discard rate for specimens below 10 cm in length; widespread distribution of recruits, although some nursery areas can be defined. A fluctuating pattern in the BI within the range 6–10 kg was detected
Mullus surmuletus	6.4 15.1	1999 1997	15.6	1996	120–350	180	Occurs mainly on the shelf
Pagellus erythrinus	1.6 9.3	1994 1998	–	–	80–330	120	Fished exclusively on the shelf
Peristedion cataphractum	–	–	0.5 4.4	2001 2002	40–350	190	Fished both on the shelf and on the slope although the highest value of BI occurs on the slope
Phycis blennoides	–	–	5.1 9.4	1995 1996	50–540	110	Mainly found on the slope. Only slight irregular variations of 5–7 kg were evident in the BI
Galeus melastomus	–	–	18.9 28.9	2002 2000	70–530	330	Collected only on the slope and fished over a wide depth range (250–680 m); totally discarded. No trend evident
Mustelus mustelus	4.7 18.6	2001 2000	–	–	–	–	Collected only on the shelf
Raja clavata	4.0 15.2	1995 1999	2.2 8.4	1995 1999	160–890	550	Caught in a wide depth range. Abundance indexes showed an irregular temporal pattern. A sharp decline has been noticed in the most recent surveys
Scyliorhinus canicula	5.0 8.2	2001 2002	–	–	90–490	300	Found both on the slope and the shelf
Aristaeomorpha foliacea	–	–	6.0 20.0	1995 1994	16–74	36	Exclusively caught in the deep waters although occasionally found at lesser depth (150–250 m); almost all sizes are retained (no or very low discard); not considering the 1994 datum, a positive trend was detected. An inversion of the trend has been noted in the most recent surveys
Nephrops norvegicus	0.1	1996 and 1999	2.8 7.3	1997 1996	15–76	31–37	Sought after by fishermen almost exclusively on the upper slope; only a scanty catch is taken on the outer edge of the shelf; no trend
Parapenaeus longirostris	3.9 14.1	1994, 1995 1999	7.4 27.1	1994 1999	9–39	18–23	Wide bathymetric distribution (80–700 m) but fishing grounds located mainly between 100 and 500 m; low discard incidence below CL of 20 mm; some nursery areas were identified. With the only exception of 1997 data, a positive and significant trend was detected for the DI. An inversion of the trend has been noted in the most recent surveys
Eledone cirrhosa	2.1 8.3	1997 1994	1.3 5.3	1995 1994	10–130	80	Juveniles are highly prized
Eledone moschata	9.2 12.6	2002 2000	–	–	20–170	70	A more "coastal" species than the congener; caught exclusively on the shelf
Illex coindetii	5.1 10.0	1997 1999	–	–	30–250	110	In spite of a wide depth distribution, this squid was mainly found on the shelf

Table 2. Inventory of existing information on the life-history characteristics of target species (fish and crustaceans) at IRMA–CNR (data from area A). Weight in grams and length in millimetres (unless otherwise specified). Lengths refer to total and carapace length for fish and crustaceans, respectively. Where applicable, ranges of *a* and *b* values, as well as of length at maturity and of sex ratio, are given. Time unit: year. CI denotes the confidence interval (95%); *F* females, *M* males; *n.a*. not available

Species	Growth parameters	Length–weight relationship (allometric model: $w=al^b$)	Length at maturity	Sex ratio (F/F+M)	Total mortality (Z)	Natural mortality (M)	Spawning season	Recruitment season
Helicolenus dactylopterus	F+M: L_∞=392; K=0.127; t_0= –1.46	F+M: *a*=0.0000129; *b*=3.05	F=200	0.47	F+M=0.64	F+M=0.31	–	All year round
Merluccius merluccius	F: L_∞=705; K=0.18; t_0= –0.10 M: L_∞=494; K=0.29; t_0= –0.01	F: *a*=0.0000038; *b*=3.12; M: *a*=0.00000461–0.00000408; *b*=3.08–3.10	F=335; M=215–280	0.44–0.52	F=0.78 (CI=0.74–0.83) M=1.34 (CI=1.29–1.39)	F=0.30 M=0.45	All year round	All year round
Mullus barbatus	F: L_∞=235; K=0.60 M: L_∞=202; K=0.65	F: *a*=0.000189–0.0000080; *b*=2.90–3.07; M: *a*=0.0000304–0.00000108; *b*=2.79–3.00	F=150–160 M=140	0.43–0.62	F=2.28 (CI=2.06–2.50) M=2.74 (CI=2.183.29)	F= 1.10 M=1.20	Spring–summer	Summer–autumn
Mullus surmuletus	F: L_∞=290; K=0.48; t_0= –0.84 M: L_∞=250; K=0.50; t_0= –0.20	F: *a*=0.0000209–0.0000100; *b*=2.90–3.04; M: *a*=0.0000166–0.00000670; *b*=2.94–3.11	F=195	0.51–0.58	F=1.68 (CI=1.57–1.79) M=1.85 (CI=1.73–1.97)	F= 0.90 M=0.80	Spring–summer	Summer–autumn
Pagellus erythrinus	F+M: L_∞ =380; K=0.18; t_0= –0.71	F: *a*=0.0000438–0.0000288; *b*=2.78–2.85; M: *a*=0.0000347–0.0000221; *b*=2.81–2.91	F=120–130 M=160–170	0.84–0.92	F+M: 0.67 (CI=0.60–0.73)	F+M= 0.40	Spring–summer	Mainly autumn
Peristedion cataphractum	F: L_∞=434; K=0.20; t_0= –0.39 M: L_∞=456; K=0.175; t_0= –0.48	F+M (length in cm): *a*=0.00428; *b*=3.10	F=210 M=230–240	0.54	–	–	Spring–summer	Summer–autumn
Phycis blennoides	F: L_∞=681; K=0.22; t_0= –0.15 M: L_∞=471; K=0.38; t_0= –0.03	F: *a*=0.0000438–0.0000288; *b*=2.78–2.85; M: *a*=0.0000347–0.0000221; *b*=2.81–2.91	F=313	–	F=0.88 M=1.41	F=0.35 M=0.58	Autumn	Spring
Raja clavata	F: L_∞=1265; K=0.098; t_0= –0.51 M: L_∞=1167; K=0.106; t_0= –0.41	F: *a*=0.0000438–0.0000288; *b*=2.78–2.85; M: *a*=0.0000347–0.0000221; *b*=2.81–2.91	F=770–790 M=570–590	0.39–0.49	F (n.a.) M (n.a.)	F (n.a.) M (n.a.)	All year round, with a peak in autumn	n.a.
Aristaeomorpha foliacea	F: L_∞ =65.8; K = 0.52; t_0= –0.23 M: *a*=26.3; *b*=3.94 (linear growth; b=slope)	F: *a*=0.00176–0.00210; *b*=2.51–2.56; M: *a*=0.00116–0.00135; *b*=2.65–2.69	F=42 M=30–33	0.43–0.49	F=1.18 (CI=1.09–1.27)	F=0.40	Summer–autumn	Spring
Nephrops norvegicus	F: L_∞=53.0; K=0.14; t_0= –0.5 M : L_∞=62.0; K=0.13; t_0= –0.5	F: *a*=0.000440; *b*=3.133; M: *a*=0.000424; b=3.158; *b*=2.81–2.91	F=30–32	0.40–0.49	F=0.68 (CI=0.63–0.73) M=0.42 (CI=0.40–0.44)	F and M=0.20	Summer–autumn (berried)	Autumn
Parapenaeus longirostris	F: L_∞=40.9; K=0.71; M : L_∞=34.3; K=0.73	F: *a*=0.00244–0.00315; *b*=2.48–2.55; M: *a*=0.00271–0.00406; *b*=2.40–2.50	F=24 M=19	0.57–0.61	F=3.37 (CI=3.30–3.44) M=3.33 (CI=3.17–3.49)	F=1.20 M=1.30	Late summer–late winter	Peak in autumn

4. Discussion and conclusions

The most striking features of the figures reported above consist in their suggestion that there is an overall steady state of the demersal resources in the Strait of Sicily with even some increase in the local index of abundance for some species (i.e., the red shrimp, *A. foliacea*, or the deep-water pink shrimp, *P. longirostris*). That might create some perplexity in non-specialists, fishermen and politicians, given the overfishing generally recognized by scientists and the compliance of the fishermen operating in the Strait of Sicily.

Besides the well known problems in obtaining precise and accurate standing-stock estimates, stability does not mean necessarily "good shape", but only the capability of the investigated resource to withstand a high level of fishing pressure. Although not yet clarified and modelled, the reasons for such resilience likely reflect the interaction amongst spatial complexity, "high compensation" or "robust" stock–recruitment relationships (or recruit migration from less exploited neighbouring fishing grounds) and the adaptability of the fishing fleets, which switch to the most abundant species/fishing grounds year by year. In particular, it is worth underlining Caddy's (1990) hypothesis of "refugia" which allows a reduced or no longer available parental stock to maintain the standing stock by recruitment.

As matter of fact, the bulk of the trawl catches in the Strait of Sicily is nowadays composed of recruits whose growth is enhanced by the reduced inter-specific competition. Recruits also represent the most abundant specimens (up 90%) in the MEDITS and the GRUND catches. Since recruitment might show spatial and temporal fluctuations, both in the absolute values and in time of occurrence, whereas the experimental survey can cover only a limited temporal window, it is likely that the steady state or trends detected for different species could be correlated with the "good" or "bad" recruitment years enhanced or smoothed out by the synchrony between the biological and the survey calendars.

In practice, experimental data suggest (as does also a comparison of the total and natural mortality values given in Table 2) that all the demersal stocks of the Strait of Sicily fluctuate around the minimum asymptotic level of a Fox-like surplus-production model with a limited possibility to get out of the "trough", given the high efficiency and adaptability of the trawler fleets.

In fact, an historical retrospective indicates that the capacity of fleets fishing in the Strait of Sicily corresponding to the maximum sustainable yield for all demersal species was surpassed during the late 1970s–early 1980s (Levi 1988). As an example of such decline, the hourly catch rate for the pooled demersal resources trawled along the upper slope decreased from about 30–40 kg in the early 1970s to 10–20 kg in the late 1990s (Levi *et al.* 2001). Another example comes from the analysis of the discard rate (a rather good index of the "shape" of a trawl fishery); from 1996 to 2000, the percentage of the total catch of Mazara trawlers discarded decreased from 50% to 20%. This trend became more relevant considering that, in the mid-1980s, discards in the area consisted of about 60–70% of the trawler catches (Levi *et al.* 2001). Further indexes of overexploitation can be found in the rarefaction of the large-size sedentary and slow-growing fishes, such as *Peristedion cataphractum* (Pizzicori *et al.* 1995) and *Helicolenus dactylopterus* (Ragonese and Reale 1995); for the latter species, in particular, it is worth noting the estimated differential between the recent (2 years) and "pristine" (5 years) critical ages (Ragonese and Reale 1992). This scenario is supported also by the ineffectiveness of the management tools applied both by national and regional administrations, among which the most relevant were:

- trawling prohibition within three nautical miles from the coast (law of 14 July 1965, No.963)
- compulsory 45-day trawling ban (since 1983)
- reduction in the fleet size.

It is true that enforcement and control problems, together with other advantages (for example, trawling with a mesh size of less than 40 mm is allowed under Sicilian regional rules), have contributed to the inefficacy of these management actions, and a worse situation could have been attained without them; nevertheless, no effective stock rebuilding has been detected.

Notwithstanding the limitations and drawbacks, the data gathered during the experimental trawl surveys are very precious because they allow a regular and consistent check of the stock status, on the one hand, but (a most important feature) they have also demonstrated some capability to rebuild the resources, thanks to sustained recruitment. The main problem will consist in figuring out a proper management scheme in order to avoid an excessive concentration of the fishing effort where "good" recruitment occurs. The inclusion of the spatial factor in modeling by individualizing unit fishing grounds to be managed on an individual basis might be the challenge for the future.

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Commercial demersal marine species of Libya

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Abstract

This study concentrated on the commercial species of the Libyan coastal seas. There are 34 crustacean, 10 cephalopod and 5 sponge species, which are commercially important and have been recorded in this study. Information on trawlable and untrawlable areas was collected. The eastern area of Musrata is untrawlable; the best trawlable area is from the west of Musrata to the Tunisian–Libyan border. Two commercially important shrimp species *Penaeus kerathurus* and *P. longirostris* were also observed to be more abundant in this western area than in the eastern area. Cephalopods were recorded at all sampled stations. Further studies using trawl survey data are needed in Libyan waters in order to produce useful information on Libyan demersal species.

1. Introduction

Studies of marine organisms in the eastern part of Libya have been conducted since the beginning of the twentieth century (Stephenson 1923). The first map showing the locations of fishes and economically valuable sponges in the Libyan marine waters was also drawn up at the beginning of the twentieth century (Scordia 1937). A quantitative inventory of the different species of planktonic and benthic marine organisms along the Libyan coast was produced and further detailed studies were carried out (Pérès 1967; Sogreah 1977; Gashout *et al.* 1992, 2002).

Bottom-dwelling marine organisms are considered economically important in Libya. Some Libyans make their living from this marine wealth. Moreover, certain bottom-living marine animals are used as food and are considered commercially important, giving a strong support to the national economy. The trade in fishery products started in Libya in 1952 (Serbetis 1952).

Recently (1993–1994), the Marine Biology Research Centre (MBRC) staff, with a team of experts from the LIBFISH project and the Benthic Department at MRBC, has carried out a detailed trawl survey in Libyan marine waters. The objective of this project is to assess the fish stocks in these waters. Since there was an important output from this trawling study (Gashout *et al.* 2002), the aim of the present study is focused on the distribution of commercial fauna other than the demersal fish by-catch in Libyan waters (Lamboeuf *et al.* 1995).

2. Materials and methods

The commercial demersal marine fauna was collected by the MBRC Benthic Department staff in 1993–1994 during six cruises carried out by the LIBFISH Project; 108 stations,

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distributed all over the Libyan marine coastal waters, were visited. The coast was divided into 24 transect lines. In each line, seven different depths (25, 50, 75, 100, 150, 200 and 400 m) were chosen. However, the depth range from which the benthic animals were actually collected was 36–282 m (Table 1); this was determined by the trawlable and untrawlable grounds (Sogreah 1977; Contransimex 1977).

Table 1. Summary of trawling surveys in Libyan waters during 1993–1994

Cruise number	Trawling period	Area studied	Lat./long. (approx.)	Water depth (m)	Number of trawling stations		
					Proposed stations	Trawled stations	Sampled stations
I	13–27/6/93	Burdi–Ras-Lanuf	31°22'10"–23°06'33"	51–212	40	20	15
II	22–29/3/94	Tunisian border–Tripoli	34°53'54"–13°02'20"	62–210	26	25	20
III	11–23/4/94	Tunisian border–Musrata	33°31'18"–14°40'48"	36–150	94	60	28
IV	05–12/6/94	Musrata–Ras-Lanuf	31°55'18"–17°58'24"	113–248	59	12	5
V	15–20/10/94	Tunisian border–Musrata	32°33'21"–14°37'32"	40–85	70	27	27
VI	01–11/11/94	Tunisian border–Musrata	33°10'48"–12°14'60"	84–282	30	29	23
Total	13/6/93–11/11/94	Burdi–Tunisian border	34°53'54"–12°14'60" to 33°10'48"–23°06'43"	36–282	319	173	108

The bottom-trawling nets used in this study were of two kinds. The HVO (36×47 m) has a cod-end mesh size of 20 mm and is used on fishing grounds deeper than 100 m. The EXP (28×37 m) has a cod-end mesh size of 20 mm and is used on fishing grounds shallower than 100 m. The haul duration was set at 1 h. The swept areas were estimated to be 11.67 hectares for the HVO net and 9.24 hectares for the EXP net.

Most of the trawling was carried out during the daytime; however, some night trawls were carried out for comparison. At all stations, water temperature, depth and salinity were recorded. Trawling was repeated at the stations that gave a high yield of commercial species. The weight of the total catch was recorded, as well as the weight of each important commercial species of cephalopod and shrimp, in order to determine their biomass and distribution. The collected specimens were put into marked plastic bags (cooled to–10°C) for further laboratory studies.

3. Results

The 108 different stations were sampled during the six surveys along the Libyan coast (Table 1). A total of 176 different benthic species were identified: 34 crustacean species, of which four are of economic interest; 10 cephalopod species, of which six are of economic interest; and five species of commercial sponges. Table 2 shows that cephalopods were more

abundant during cruises III and VI. Moreover, the shrimp *Parapenaeus longirostris* was more abundant in deep water (>50 m), especially in cruises II, III, and VI. *Penaeus kerathurus,* which is common in shallow water (44 m; Gashout *et al.* 2002), was present at only one station (survey V; Tables 1 and 2). In these studies, three different regions were identified.

Cruise I covered the area between Ras Lanouf and Burdi near the Libyan–Egyptian border. This region had been prospected during the first trawl survey. The substrate in this region is mostly rocky, which makes it untrawlable. Only 20 hauls were carried out in this region, of which 15 were considered fruitful, e.g. when good quantities were caught. The total catch including fishes was 22,000 kg, of which, 12,000 kg were commercially important fishes, crustaceans and cephalopods (Lamboeuf *et al.* 1995).

Table 2. The distribution (in terms of stations positively sampled) of commercial demersal species during each of six different cruises

Macrobenthic species of economic value	**Cruises**					
	I	**II**	**III**	**IV**	**V**	**VI**
Cephalopods						
Loligo vulgaris	3, 6, 11, 19, 20	1, 2, 3, 5, 7, 9, 10, 11, 13, 14, 15, 16, 17, 18, 22, 23, 25	2, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 25, 26, 27, 30, 31, 33, 37, 40, 42, 45, 47, 48, 52, 57	–	1, 3, 11, 1215, 16, 17, 18, 19, 24, 25	1, 2, 3, 4, 5, 6, 9, 12
Illex spp.(totano)	3, 6, 9, 11, 13, 20	–	2, 4, 5, 6, 7, 10, 32, 57, 58, 60	1, 2, 9, 10, 12	–	7, 8, 9, 13, 14, 15, 17, 23, 24
Sepia officinalis *S. orbignyana*	1, 2, 3, 19, 20	–	2, 6, 7, 11, 15, 23, 26, 36, 37, 40, 47, 48, 58, 59, 60	1, 2, 10	13, 16, 18, 27	6, 14, 15
Octopus macropus *O. vulgaris*	2, 19	–	9, 15, 18, 21, 22, 2630, 33, 40, 45, 47, 48, 49, 50, 52	–	3, 10, 12, 13, 17	2, 7, 24
Eledone cirrhosa *E. moschata*	1, 2, 6,	2, 3, 5, 11, 13, 22, 23	5, 7, 15, 27, 59	1, 12	3	5, 6, 9, 12, 14, 15, 16, 17, 21, 24
Crustacea						
Parapenaeus longirostris	13	6, 9, 11, 16, 18, 19, 20, 22, 24	4, 5, 6, 7, 21, 52, 57	4	–	7, 8, 14, 16, 18, 23, 24, 28
Penaeus kerathurus	-	-	-	-	19	-
Squilla mantis	16	36, 27	-	-	7, 8, 9	28
Sponge spp.	3, 6, 7, 16	2, 4, 5, 13, 15, 25	1, 6, 7, 8, 17, 20, 26, 27, 40, 49, 50, 54	3	6, 10, 11, 13, 16, 19, 24	3

High diversity was recognized in this region (132 marine benthic animal species). The commercial cephalopods (*Octopus* and *Sepia*) were present at all the stations trawled in this region. In addition, *Parapenaeus longirostris* was also collected off Benghazi.

The second region covers the area between Ras Lanouf and Musrata and was surveyed by Cruise IV. The sea bottom in this region is also rocky, and it was possible to trawl only 12 out of 59 proposed stations. The benthic animals collected in this region were not abundant (21 different species). The collection was carried out at five deep stations (113, 197, 246, 248 and 282 m depths). Several species of crustaceans were collected, the most important of which was the commercial shrimp (*Parapenaeus longirostris*). The most important cephalopod species were of the genera *Sepia* and *Octopus*. In addition, there were five

commercially important sponge species: *Hippospongia communis, Spongia officinalis adriatica, S. officinalis mollissima, S. agaricina* and *S. zimocca* (grouped in Table 2).

The third region covers the area between Musrata and the Libyan–Tunisian border (Figure 1). The trawling in this region was covered by Cruises II, III, V and VI at lesser depths (41–100 m) and at greater depths (100–282 m). In order to cover this region, 220 different stations were proposed, but only 141 stations were trawled. In this region, 130 different species, such as cephalopods (of the genera *Octopus* and *Sepia*), sponges and shrimps were collected. This region appeared to be the most easily trawlable off the Libyan coast.

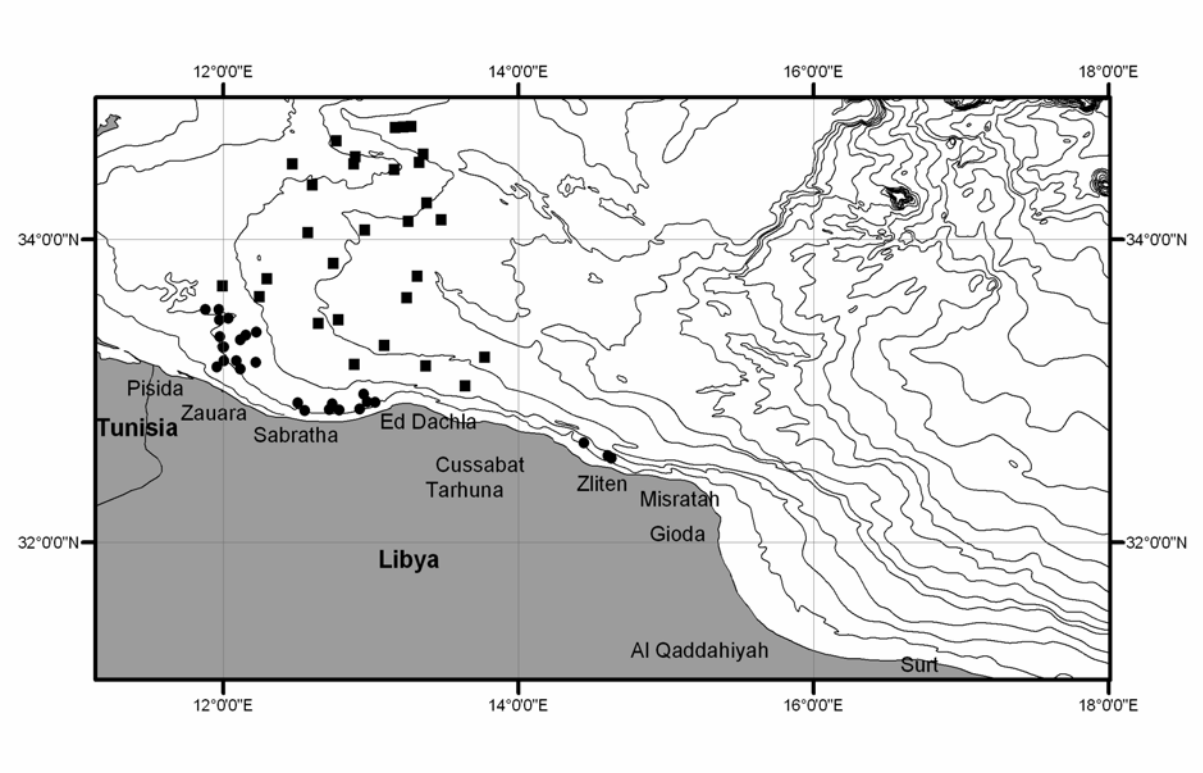

Figure 1. Trawl-survey region from Musrata to the Libyan–Tunisian border during 1993–1994 (Lamboeuf *et al.* 1995)

(●)Stations surveyed during cruises II and III

(■)Stations surveyed during cruises IV and V

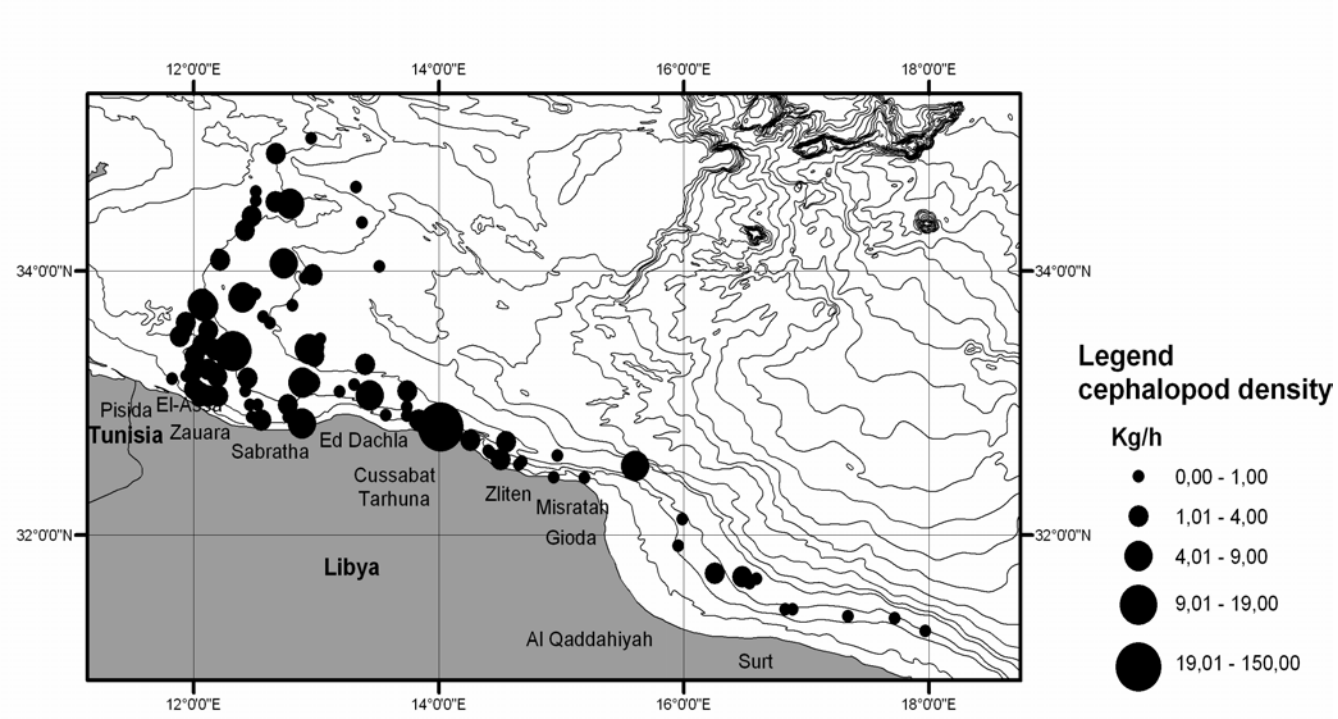

Figure 2. Cephalopod density (March–June 1994)

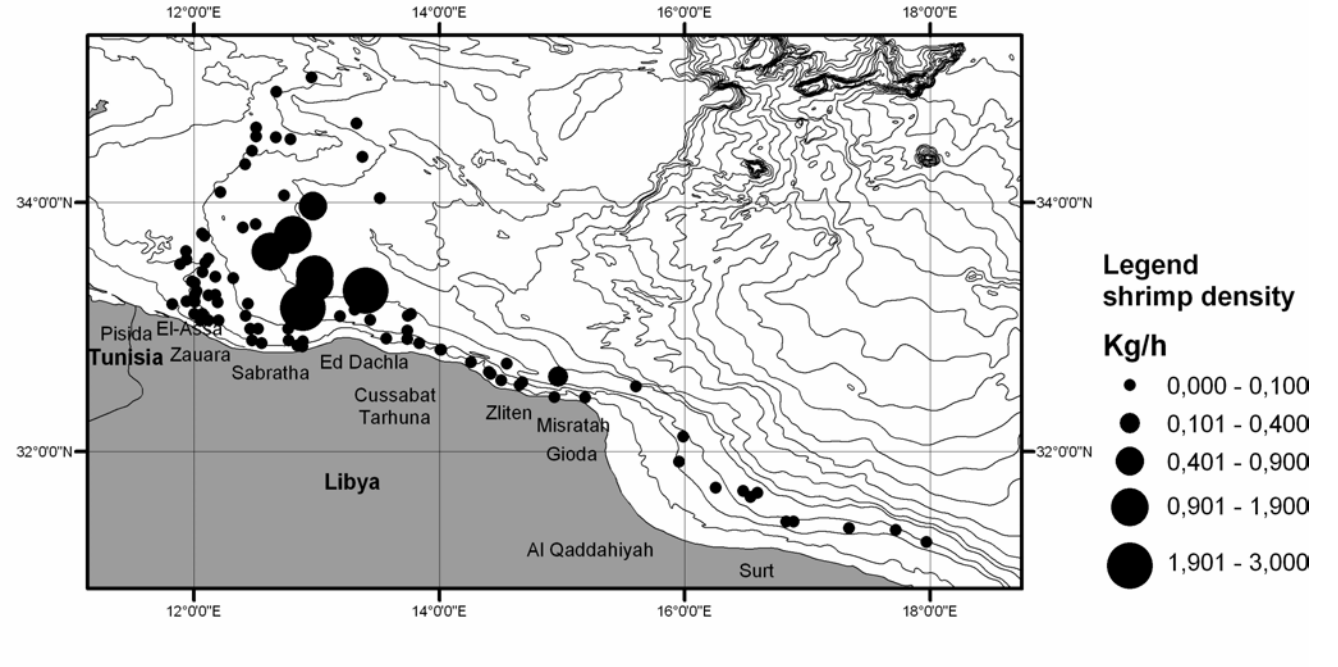

Figure 3. Shrimp density (March–June 1994)

4. Discussion and conclusions

In this study, the identification and distribution of 176 different macrobenthic animal species were determined. This study also indicated that the trawlable waters were between Musrata and the Libyan–Tunisian border. Trawling was limited in the Gulf of Sirte, off Benghazi, and El Gabel Akdar and in depths less than 200 m.

Comparing the results of this study with others (Instrupa 1975; Sogreah 1977; Contransimex 1977), the presence of cephalopods (of the genera *Octopus* and *Sepia*) at all stations studied was notable. However, the shrimp *Parapenaeus longirostris* was found only off Benghazi and from the Gulf of Sirte to the Libyan–Tunisian border. However, the shrimp *Penaeus kerathurus* was not recorded in the eastern waters, since it had already been well documented (Instrupa 1975; Contransimex 1977). This particular species was found between Musrata and the Libyan–Tunisian border, and at depths less than 100 m, as was also found by previous studies (Instrupa 1975; Sogreah 1977).

The presence of a large number of commercial cephalopod species (of the genera *Sepia* and *Octopus*), crustaceans (shrimp) and the five sponge species from Musrata to the Libyan–Tunisian border is in agreement with the previous studies (Azzouz 1969; Sogreah 1977). It was also clear from the present and the previous studies of Libyan waters that *Penaeus kerathurus* was found only in the western areas (Musrata to the Libyan–Tunisian borders). East of Musrata, this species was not recorded in this study, as also in previous studies (Instrupa 1975; Contransimex 1977).

It was obvious from this study that the waters to the east of Musrata, with the exception of certain places (Derna, Bumba, Benghazi) and shallow depths in the Gulf of Sirte (<200 m), were untrawlable. The best areas for trawling are those to the west, from Musrata to the Libyan–Tunisian border.

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Sessile megabenthic species from Tunisian littoral sites

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Abstract

Structurally complex habitats (e.g. coralligenous habitats, seagrass meadows, biogenic habitats etc.), as well as those relatively undisturbed by natural perturbations, are more adversely affected by human activities, since both kinds have the longest recovery period in terms of recolonization of the habitats by the associated fauna and flora. The disturbance of these habitats (complex and undisturbed) leads to the removal of high-biomass species as their main organisms (such as sponges) increase the topographic complexity of the sea bed.

To document this important interaction between the marine habitats and human activities (mainly fisheries), which might lead to the loss of the associated marine biodiversity, it is crucial to give an overview of the actual state of these habitats. Thus, a general picture of some examples of the main littoral benthic habitats along the Tunisian coast is presented in this document. The distribution of the main benthic species in the Gulfs of Gabès, Hammamet and Tunis is also summarized.

This review emphasizes the gaps that have to be filled by the main INSTM research programme planned for 2002–2006. Furthermore, other important national action plans were identified by Tunisia as crucial steps for the conservation of the marine ecosystems and their associated human activities within the framework of the SAPBIO Project (MAP/RAC–SPA).

All these scientific actions, to be conducted under the overall supervision of INSTM with the collaboration of an associated team of researchers from Tunisia and abroad, will focus on the development of synoptic descriptions of marine benthic biodiversity, and their quantitative analysis in the context of hypotheses derived from ecological theory.

1. Introduction

Marine biodiversity, well represented in the infra- and circalittoral levels, is mainly developed in the two most important Mediterranean benthic assemblages: the sea grass meadows (*Posidonia oceanica*) and the coralligenous. In Tunisia, both habitats have a wide geographical distribution (Topsent 1894; Seurat 1929; Canu and Bassler 1930; Molinier and Picard 1954; Pérès 1954; Ben Mustapha 1967; Ben Alaya 1969, 1972; Rützler. 1973, 1976; Ben Maiz 1984, 1995; Boudouresque *et al.* 1986; Zaouali 1993; Ben Mustapha and El Abed 2002), which is also documented in studies focusing on benthic communities of the trawling areas located over the 50-m isobaths (Anon. 1923; Le Danois 1925; Lubet and Azouz 1969; Azouz and Capapé 1971; De Gaillande 1970a, b; Ktari-Chakroun and Azouz 1971; Azouz 1966, 1973; Ben Othman 1973; etc.).

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The sea bottoms of the littoral zone of the northern Tunisian coast are mainly rocky, while those of the eastern (Hammamet Gulf) and southern (Gabès Gulf) coasts are sandy to sandy-muddy (Le Danois 1925; Azouz 1966, Ben Mustapha 1966; Poizat 1970; Ben Othman 1973; Blanpied *et al.* 1979; Ben Mustapha and Hattour 1992; Pergent and Kempf 1993; Brahim *et al.* 1994; Ben Mustapha and El Abed 2002; Ben Mustapha *et al.* 1999, 2002a).

The rocky bottoms of the northern coast offer the best substratum for colonization by very rich coralligenous assemblages (Azouz 1973; Boudouresque *et al.* 1986; Ben Mustapha *et al.* 2002a; etc.), while in "la petite Syrte" i.e the Gulf of Gabès sensu lato, and in several parts of the Hammamet Gulf, the *Posidonia* meadows show their maximum geographical distribution (Ktari-Chakroun and Azouz 1971; Ben Othman 1973; Ben Mustapha *et al.* 1999; etc.). Nevertheless, it should be emphasized again that both biocenoses are well represented all along the Tunisian coast (Azouz 1966; Pergent and Kempf 1993; Afli et Ben Mustapha 2001; Ben Mustapha and El Abed 2001, 2002; Ben Mustapha *et al.* 2002a).

In the following paragraphs, we shall review samples of Tunisian megabenthos from the circa- and infralittoral zones along the Tunisian coast (Figure 1). These data were gathered from several marine scuba-diving surveys conducted in recent years.

2. Brief overview of the marine biodiversity in the Gulfs of Gabès, Hammamet and Tunis

In a recent working group charged with highlighting the marine biodiversity hitherto recorded in the Gulfs of Gabès, Hammamet and Tunis, several researchers from INSTM made a comprehensive review of the bibliography on this subject (Afli and Ben Mustapha 2001; Bradai 2001, 2002; Ben Mustapha *et al.* 2002b; Afli and Riveill 2002; Langar 2002; Afli 2002; Sellem 2002; Ben Mustapha and El Abed 2002; Ben Mustapha *et al.*[1]). The results are shown in Figure 2.

A comparison of the marine biodiversity of the three main Tunisian gulfs is not possible due to the artifact resulting from the difference between the stronger research programmes developed in the Gulfs of Gabès and Tunis and the lower scientific interest in the biodiversity in the Gulf of Hammamet.

[1] Ben Mustapha, K., Boury-Esnault, N., Kartas, F., El Abed, A., Zarrouk, S. et Souissi, A. Sponge diversity in the Tunisian waters. Società Italiana di Biologia Marina, 34th Congress. Sousse, May 2003 (submitted).

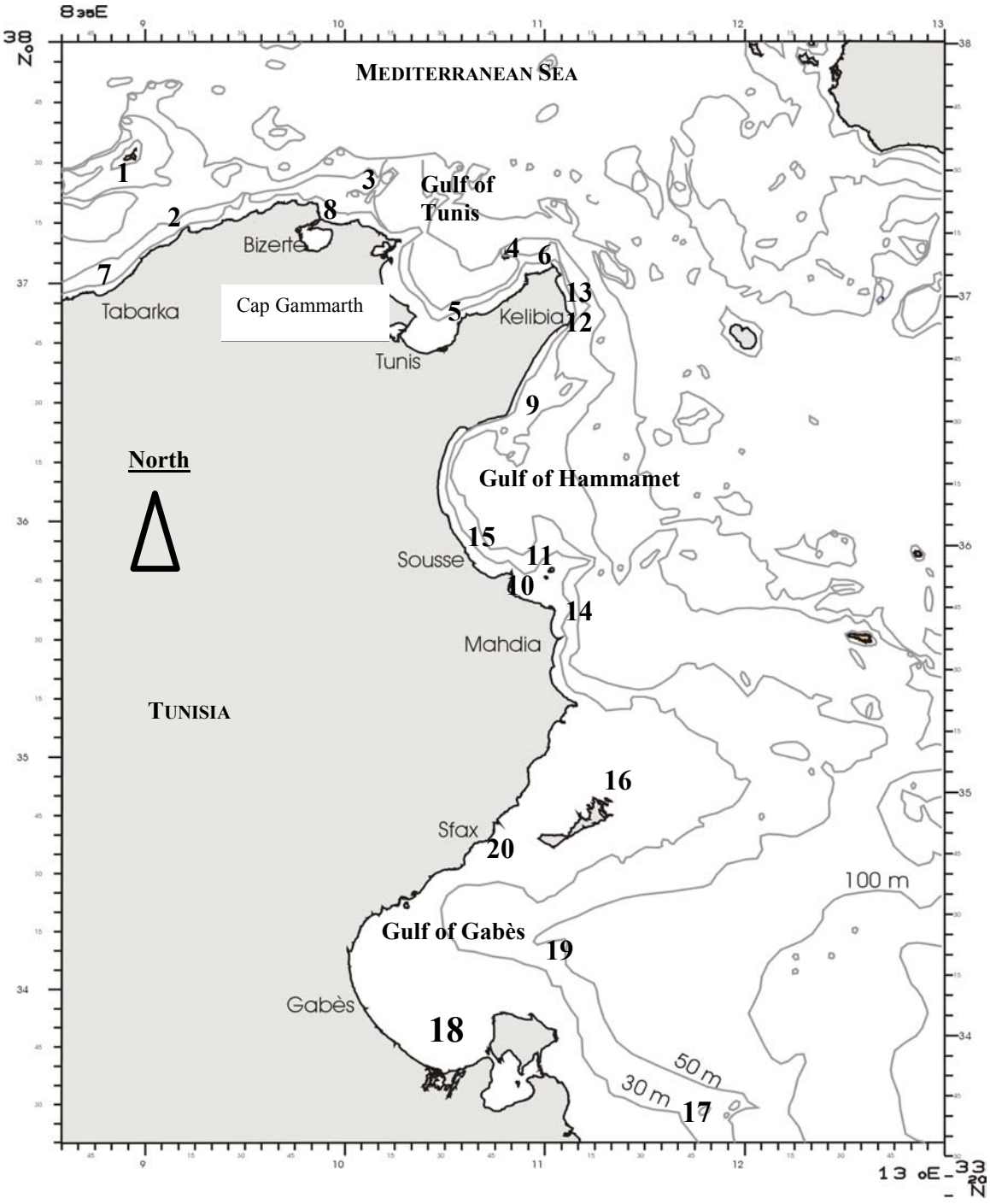

Figure 1. Location of the main areas mentioned in this paper. 1. Galite Island; 2. Fratelli Island; 3. Cani Island; 4. Zembra–Zembretta area; 5 Cap Fartas; 6. Cap Bon area; 7 Tabarka; 8 Bizerte; 9. Maamoura and Korba Banks; 10. Monastir area; 11. Kuriat area; 12. Kelibia area; 13. Kerkouène area; 14. Salakta; 15. Sousse; 16. Kerkennah platier; 17. Zarzis Banks; 18. Djerba Island; 19. Central area of the Gulf of Gabès; 20. Sfax

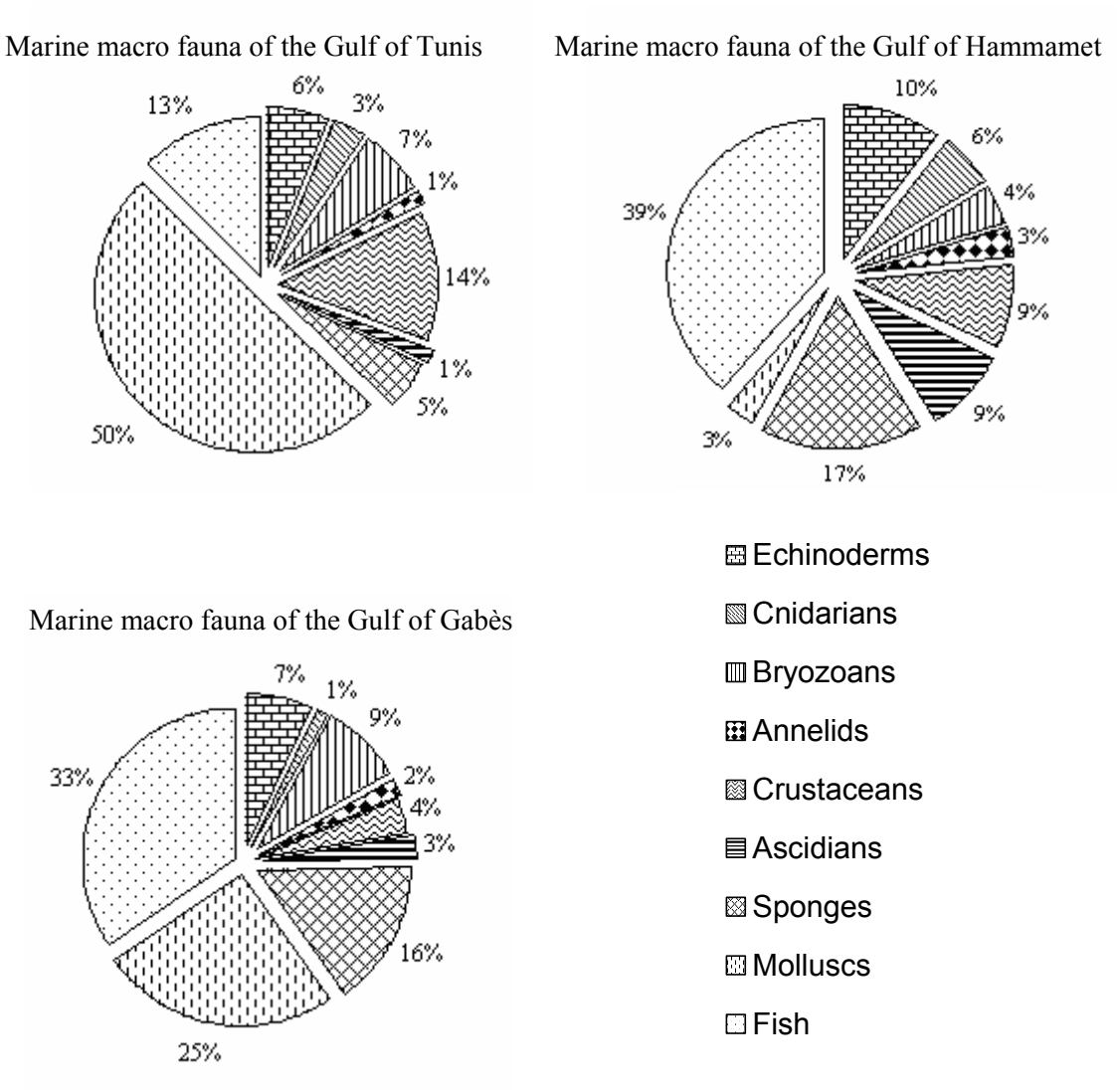

Figure 2. Distribution of the main phyla in the Gulfs of Tunis, Hammamet and Gabès

3. Megabenthic sessile species from several Tunisian sites

3.1 Northern coasts

Posidonia meadows[2]

The presence of *Posidonia oceanica* meadows in this region is well documented (Ostenfeld 1918; Le Danois 1925; Chambost 1928; Molinier and Picard 1954; Lubet and Azouz 1969; Ben Alaya 1969, 1972; Azouz 1973; Boudouresque *et al.* 1986; Ben Mustapha in: Anon 1991; Ben Mustapha and El Abed 2001; Ben Mustapha et al 2002a, c; Ben Mustapha and Hattour 1992).

[2] According to Giraud (1977) *Posidonia* meadows are classified by five types in relation to the density expressed as number of shoots per square metre (type V ≤ 150 shoots/m²; type IV: 150–300 shoots/m²; type III: 300–500 shoots/m²; type II: 500–700 shoots/m²; type I > 700 shoots/m²); Augier (1986) and Meinesz and Laurent (1978) adopted a different classification (types 1, 2 and 3) based on percentage coverage, rhizome position, presence of mattes, colonization of sediments

Geographically, these meadows have a wider distribution off Bizerte and around Cani. The meadows surrounding Cani Islands reach the coast of Sidi Ali Mekki (the north-western limit of the Gulf of Tunis), extend 15 nautical miles south-east and, from that point, westwards to Cap Zebib 15 nautical miles away. Focusing on the mapping of the meadows of that area should be a priority for Tunisia, since they might be more important than the remaining ones presently spreading in the Gulf of Gabès, historically known as the most important ones in the Mediterranean (Ben Mustapha and Hattour, 1992; Pergent and Kempf 1993; Boudouresque 1997; Batisse and Jeudy de Grissac 1998; Ben Mustapha and El Abed 2001).

In Tabarka, la Galite and Fratelli, the lower limit of the meadows was found within the usual Mediterranean limits, at a depth between 30 and 40 m (Boudouresque 1997), while in the case of the meadows off Sidi Daoud (near Cap Bon), the limit varies from 23 to 27 m depth. In Zembra, these meadows reach 34 m depth, with a density varying from 150 shoots/m² (in the deepest limit) to 750 shoots/m² at 14 m depth[3].

Occasionally, the meadows' limits might reach deeper areas, such as those in the Strait of Cani–Sidi Ali Mekki, where they may be found at 41 m depth. The coverage and density of the meadows vary also from one area to another, from a density of 700 shoots/m² in Zembra (Boudouresque *et al.* 1986), 600 shoots/m² in Galite Island (Anon. 1991), 350 to 550 shoots/m² in the Sidi Daoud area and 450 to 500 shoots/m² in the Strait of Cani–Sidi Ali Mekki (Ben Mustapha et al 2002a, b)

Another area of importance is the eastern coast of the Gulf of Tunis; mainly starting from south of Sidi Daoud to Ras Fartas, where the meadows grow on detritic or rocky bottoms. If we compare the distribution of the *Posidonia oceanica* meadows in the Gulf of Tunis, as described by Ben Alaya (1969, 1972), with the data available now, we see no general degradation in terms of area coverage. We found the meadows around Cap Farina/Sidi Ali Mekki (western part of the Gulf) and those extending from Ras Fartas to Sidi Daoud (eastern part of the Gulf). We also found the barrier reef off Sidi Rais to a depth 15 m. But elsewhere, a few patches have been experiencing severe environmental conditions, such as the meadows extending from Salammbô to La Goulette (south-western Gulf of Tunis), which have already disappeared or, if they still exist, are present only as type 2 or 3; i.e meadows in very bad health. Moreover, the meadows off Cap Gammarth seem to have undergone a reduction in their inner limits (Ben Mustapha, in Anon. 1991; Ben Mustapha and Hattour, 1992; Ben Mustapha *et al.* 2002a, b; Zaouali (personal communication).

Coralligenous assemblages and rocky habitats

A number of sites showed a high diversity of sessile macrobenthic organisms representing healthy coralligenous assemblages. However, a few black spots were recorded, mainly in the Gulf of Tunis. Hence, in general, the biota at a few stations are changing from detritic to muddy ones. Consequently, in such areas, the sessile macro-benthic representatives of detritic and rocky bottoms of the circalittoral level, such as the calcareous red algae *Lithothamnionum corallioides, Phymatolithon (Lithothamnium) calcareum,* the sponges *Suberites domuncula, Petrosia ficiformis, Agelas* sp., *Axinella canabina, Spirastrella cunctatrix,* are replaced by representatives of muddy bottoms, e.g the anthozoan *Alcyonium palmatum,* the bryozoan, *Pentapora fascialis*, the echinoderms *Holothuria forksali,*

[3] Mission de zonation des habitats marins benthiques du parc marin de Zembra Zembretta (INSTM–CAR/ASP–APAL)

Ophioderma longicaudum, the ascidian *Microcosmus* sp.*,* and the cnidarian *Amphiura* sp. (Pérès, 1985).

Nevertheless, apart from such local areas and despite the mortality of macrobenthic invertebrates that occurred in the region in 1999 (Ben Mustapha and El Abed 2001), coralligenous assemblages were well represented in the circalittoral zone, both from rocky and detritic bottoms. Indeed, the Cap Bon area shows one of the highest levels of variability of macrobenthic assemblages, with populations of sponges, such as *Clathria* spp., *Raspaciona* sp., *Anchinoe* sp., *Timea* spp., reaching a coverage of up to 1 m² in horizontal and sub-horizontal exposures. Table 1 lists the sponge species recognized in situ.

Table 1. Sponges from coralligenous assemblages

Taxonomic group	**Species**
Sponges	*Ircinia fasciculata*, *I. oros, Ircinia* sp., *Cacospongia mollior, Cacospongia* sp., *Sarcotragus* spp., *Dysidea* sp., *Petrosia ficiformis, Calyx niceansis*, *Haliclona* spp., *Chalinella* spp. Representatives of the Order *Poecilosclerida* were abundant, with several species of *Anchinoe, Clathria, Microciona, Artemisina, Raspaciona, Hemimycale collumela, Crambe crambe, Crambe* sp., *Timea* sp., *Cliona viridis, Cliona* sp., *Agelas oroides, Agelas* sp., *Axinella canabina, A. polypoide, Oscarella lobularis*

In the marine protected area of Zembra–Zembretta, a recent survey showed well developed assemblages of benthic sessile species (unpublished), with a high density (expressed as number of individuals/m²), such as the madreporarians *Eunicella singularis* (30 colonies/m²) and *Astroides calycularis* (2,935 colonies/m²), the bryozoan *Myriapora truncata* (162 colonies/m²) and the green alga *Flabellia petiola* (755 thalli/m²).

Finally, also in this very interesting area (Cap Bon–Zembra/Zembretta–Sidi Daoud), we recorded:

- A rare gorgonian, *Ellisella* sp., recorded only around the Spanish island of Chafarinas off the Moroccan Mediterranean coast (Calvin Calvo, 1995); we found it at a depth of 47 m off Sidi Daoud, on a very rich coastal detritic assemblage.
- *Caulerpa racemosa*, listed for several stations on detritic (e.g. south-east of Zembretta Island at 45 m. depth), sandy (e.g. north of Haouaria at 30 m depth) or rocky bottoms (e.g. Cani Island at 12 m depth; Sidi Daoud at 1.5 m depth), as well as on muddy substrate in the marina of Bizerta, at 2–3 m depth (Djallouli 2000; Ben Mustapha and El Abed 2001). *C. racemosa*, recorded in the marine protected area (MPA) of Zembra Island at 26 m depth in 1999 (unpublished) now reach a depth of 34 m in this MPA.
- *Caulerpa taxifolia* and *C. racemosa*, recorded for the first time at 46 m depth 0.2 nautical miles south of Cap Bon, on coralligenous assemblages, whereas the same location was free of these two algae during a survey made in 1992 (unpublished).
- The caves at 30 m depth, west of "Cathedral Rock" on Zembra Island, where the sponge population was well represented, mainly by species of the Orders *Agelasida, Poecilosclerida,* and *Haplosclerida*. In one of these caves, a living pharetronid sponge, *Petrobiona massilensis*, was recorded for the first time in Tunisia Boudouresque *et al.* 1986; Ben Mustapha and El Abed 2002; (Ben Mustapha, unpublished).

- An anomalous rocky-bottom ridge at 35 m. depth, rising to 28 m depth, and extending from Zembra to Zembretta. The macrobenthic fauna there is very rich, with gorgonians covering all substrata, such as *Eunicella singularis*, with a density of 17–24 colonies/m², *Eunicella cavoloni*, with a low density of 3 colonies/m², and *Leptogorgia sarmentosa*, with a density of < 1/m². Bryozoans are represented mainly by *Myriapora truncata, Pentapora fasciatis* and *Sertella* sp.; and species of the genera *Aplidium* and *Clavellina* are the most common ascidians. The sponge population is well represented, mainly with high densities, by *Axinella canabina, A. damicormis, A. poypoides, Agelas* sp., *Petrosia ficiformis, Spongia officinalis, Hippospongia communis, Sarcotragus muscarum. Sarcotragus* sp., *Ircinia* sp., *Cacospongia mollior,* as well a number of species of the Order Poecilosclerida, such as *Mycale* sp., *Hemimycale columella, Myxilla* sp. and *Anchinoe* sp., *Microciona* sp., *Clathria* sp., *Crambe* sp. *Eudendium racemosum* and species of the Sub-family Aglopheniinae are the most common hydrozoans. Regarding the benthic flora, cystoseirans are the most common representatives of a photophilic population on horizontal substrata that includes a high density of *Dictyota dichotoma*, while *Udotea petiola* and *Halimeda tuna* have a higher density on the vertical faces of the rocky-bottom ridge.

3.2 Eastern and southern coasts

The very large area from Cap Bon to the Tunisian–Libyan border has very interesting bionomic features due to the presence of several banks off the eastern coast of Tunisia, two large islands (Djerba and Kerkennah) and the Kerkennah "platier" (Burollet *et al.* 1979).

Korba and Maamoura Banks

These banks have a depth of 26–33 m east of the Gulf of Hammamet, with patches of dense *Posidonia* meadows. Inter-mattes are coarse detritic bottoms, covering a **rocky slab** (Maamoura Bank) with a coralligenous assemblage (*Phymatolithon (Lithothamnium) calcareum* and *Eunicella singularis*). As recorded by Ben Mustapha and Hattour (1992), the dense meadows growing on mattes are of type III. The sponge and ascidian fauna is very rich (Table 2).

Table 2. Sponge and ascidian species observed on Korba and Maamoura Banks

Taxonomic group	Species
Sponges	*Cliona vastifica, C. viridis, Ircinia oros, I. fasciculata, Sarcotragus muscarum, Cacospongia mollior, Scopalyna lophyropoda, Axinella poypoides, Agelas* sp., *Hemimycale columella, Anchinoe fictitius, Hamigera hamigera, Crambe crambe, Petrosia dura, Disydea fragilis, D. tupha, Aplysilla sulfurea*
Ascidians	*Aplidium conicum, A. tabarquensis, Pseudosdistoma crucigaster, Pseudodistoma* sp., *Didemnum maculosum, Diplosoma* sp., *Polycitor adriaticum, Polycitor* sp.

Sponges, ascidians and bryozoans of the *Posidonia* meadows off the Sahel coasts: Kerkennah platier and Fora Mostafa

The meadows start from the Sahel coasts (i.e. the Sousse–Monastir area), continue eastwards to Kuriat Island, and southwards to the Kerkennah platier (Amari 1984) and bordering it on its eastern and southern sides (Ben Mustapha and El Abed 2002). These very extended

meadows, of types 2 and 3 (coverage between 50% and 100%, generally growing on mattes up to 1 m high) can reach depths of 27–30 m. We consider it a very large area of sea grass development. The species richness of the associated fauna differs from place to place. We briefly focus on the meadows of the Kerkennah platier (i.e. at a depth of 15–25 m and those in a few other places, such as the port of Sousse, Monastir, the channel between Kuriat Island and Monastir at 26 m depth, and Cap Salakta.

Sousse: The *Posidonia* meadows off Sousse are increasingly confronted by the presence of the invasive alga *Caulerpa taxifolia*, reported in Tunisian waters by Langar *et al.* (2000) for the first time. The first investigations revealed the presence of sea grass mattes 2 m high, testimony to a dense and healthy meadow. At present, and in general, the perimeter of the mattes is still occupied by *Posidonia,* while the bottom of the central area, a sandy or muddy–sandy bottom, is covered by dead leaves of *Posidonia*. The limit of the sea grass meadows, at 15–17 m depth, is of type III (a few *Posidonia* rhizomes remain with rare shoots and a coverage of 5–30%, in a muddy bottom), which did not allow the fixation of a pre-coralligenous lower stratum on the rhizomes. We listed only two species of sponges: *Dysidea fragilis* and *Ircinia fasciculata*, and two ascidians, *Aplidium conicum* and *Aplidium* sp.; there is also a very scarce presence of algae such as *Udotea petiola, Halimeda tuna* and *Lithophyllum* sp.; *Codium bursa* was present on the muddy bottom with *Caulerpa prolifera*. This depopulated area, as well as all the space freed by the action of merchant-ship anchors (the anchorage area) is invaded by *Caulerpa taxifolia*, partially replacing the *Caulerpa prolifera* meadow.

Kuriat–Monastir Channel: Despite the presence of type II *Posidonia* meadows, with 600 shoots/m², the macrobenthic sessile fauna was surprisingly impoverished, in comparison with other places such as the banks described before. Other observed species are listed in Table 3.

Table 3. Sponge, ascidians and bryozoans species observed in the Kuriat–Monastir Channel

Taxonomic group	**Species**
Sponges	*Dictionella* sp., *Scopalina lophyropoda, Tethya aurantium, Dysidea avara, Ircinia oros, Sarcotragus muscarum*
Ascidians	*Aplidium conicum*, *Polycitor adriaticum*
Bryozoans	*Sertella septentrionalis*

Salakta: The bottoms in the southern area of Salakta at a depth of 6 m are sandy, with several *Posidonia* meadows and rocky slabs. The mattes of the *Posidonia* meadows (type III, with a density of 750 shoot/m²) may be higher than 2 m. The sandy bottom is covered by *Cymodocea nodosa* or, from place to place, by *Zostera nolti*. *Caulerpa racemosa* and *Caulerpa prolifera* were both recorded. Sponges and ascidians were not abundant (see Table 4); madreporarian skeletons belonging to *Leptopsammia pruvoti* and *Cladocora cespitosa* were also recorded but were very rare**.**

Table 4. Sponge and ascidians species observed in Salakta

Taxonomic group	**Species**
Sponges	*Tethya aurentium, Tethya citrina, Dysidea fragilis, Sarcotragus muscarum*
Ascidians	*Crambe crambe*, *Polycitor adriaticum, Halocynthia papillosa*

Kerkennah platier: Several stations around the platier were visited. Meadows cover a very large area, all around the Kerkennah shallow-water platier. In the north they reach 37 m depth off Chebba, while the eastern and southern limits are less deep, between 18 and 25 m. In these areas, the meadows are less dense than those growing in the northern region, but both have a density (in shoots/m²) typical of type I and II meadows. However, the density is lower than that found in other similar types of meadow (Ben Mustapha and Hattour 1992; Ben Mustapha *et al*. 1999; Ben Mustapha and El Abed 2001), due to illegal trawling all along the eastern coast of Kerkennah Island (Ramos Esplá A., personal communication). These meadows are very rich in sponge, hydrozoan, bryozoan and ascidian species. The most common and representative species are listed in Table 5.

Table 5. Most representative sponge, anthozoan, bryozoan, ascidian and alga species recorded on the Kerkennah platier

Taxonomic group	Species
Sponges	*Cliona vastifica, C. viridis, Cliona* sp., *Aplysilla sulfurea, Chondrilla nucula, Hemimycale columella, Mycale massa, Anchinoe paupertas, A. tenacior, Haliclona mediterranea, Cacopsongia mollior, Hippospongia communis, Ircinia fasciculata, Sarcotragus* sp., *Dysidea fragilis*
Anthozoans	*Caryophyllia* sp., *Cladocora cespitosa, Leptopsammia pruvoti, Balanophyllia* sp., *Plumularia* sp., *Halochordyle disticha*
Bryozoans	*Filograna implexa; Sertella septentrionalis*
Ascidians	*Polycitor* sp., *Botryllus schlosseri, Aplidium conicum, Clavelina nana, Ecteinacidia* sp., *Diazona* sp.
Algae	*Sphaerococcus* sp., *Lithothamnium* sp., *Pseudolithophyllum expansum, Halimeda tuna, Udotea petiola*

Fora Mostafa (central part of the Gulf of Gabès): This small basin is well known as a shrimp-trawling area in the eastern/south-eastern Gulf of Gabès. Despite the muddy bottoms and the intense shrimp trawling in this area (Hattour 1991; Caddy 1993, 1995; Ben Mustapha 1995; El Abed and Hattour 1997; etc.), a few patches of detritic biota, at 40–55 m depth, with coralligenous assemblage, are still present, with numerous calcareous Rhodophyceae, such as *Phymatolithon (Lithothamnium) calcareum* and *Lithothamnion coralloides*. The predominant species recorded were sponges, and the echinoderm *Cucumaria* sp. The most abundant sponges were *Geodia cydonium* and *Fasciospongia cavernosa*. Less predominant species of sponges were *Verongia aerophoba, Dictyonella* sp., *Suberites domuncula, Cacopsongia mollior, Ircinia muscarum, Spongia nitens* and *Hippospongia communis*. The gorgonian *Eunicella singularis* was rarely recorded.

3.3 The banks off the Zarzis coast

These banks are the most important topographical feature of this area. The first bank, Ras Dzira, is 12 nautical miles east of Zarzis at a depth of 6–11 m, followed by Bancacou and Messioua Banks, respectively located at 20 to 30 nautical miles east of Zarzis, at a depth of 20–33 m. The farthest east is El Greco Bank, 35 nautical miles offshore at a depth of 25–35 m. All these banks are covered by sea grass meadows, mainly of *Posidonia oceanica*, while in the sandy bottom of the inter-matte channels, *Cymodocea nodosa* is well represented. Nevertheless, rocky and bio-constructed bottoms are also a notable feature of these banks, especially those of Messioua and El Greco.

Posidonia meadows

We observed several types of development, from type IV (i.e. the least healthy type in terms of shoots/m²) in some parts of Bancacou and at some stations on Messioua Bank at a depth of 20–30 m to type I (i.e. the healthiest one) on the Messioua and El Greco Banks. These meadows may be present as a continuous covering, as seen on the El Greco, Messioua and Ras Dzira Banks, or may be present as large patches, as seen at Bancacou and at some stations on the Messioua and El Greco Banks. The *Posidonia* mattes may be short (30 cm high) or non-existent, mainly near the deepest limit of the meadows (as seen at 30 m depth on Messioua) or even at 20 m depth in Bancacou. Elsewhere, the height of the matte varies between 0.7 and 1.5 m. The coverage also varies from less than 40 % (Messioua and Bancacou) to nearly 100 % (Messioua, Ras Dzira and El Greco). The density (in shoots/m²) is very high in general on the Messioua, El Greco and Ras Dzira Banks, varying from 525 (meadows of type II) to 1,125 shoots/m² (meadows of Type V)[4]. The latter observation means that, for such a range of depth, these meadows have actually the highest density in the whole Mediterranean region (Ben Mustapha *et al.* 2002b). But in several parts of Bancacou and at the deepest stations on Messioua, this density is low, varying from 350 to 500 shots/m² (type III and type II). The presence of such meadows, which in several places are boundary meadows of type I or II in the deep area of the Messioua Bank on detritic bottoms (33 m depth), or in several parts of Bancacou at depths of 20–22 m, can be explained not only by the reduced luminosity with increasing depth, but also, and principally, by illegal trawling in the region, since several trawl tracks were observed.

Macrobenthic assemblages

Rocky bottoms were also encountered on the Messioua and El Greco Banks, but their morphology differs. Messioua's rocky bottoms are mainly of the rock-slab type, even though they may be up to 40 cm high, whereas those of El Greco Bank are of both types: slabs and blocks that may be up to 2 m high. Biotic constructions are also very common, due principally to the action of calcareous corallinacean species.

The macrobenthic sessile fauna (and flora) is very well represented, mainly by filter-feeding invertebrates, such as sponges and ascidians. Over all three banks, hydrozoans, madreporians, sponges, ascidians and bryozoans were represented in various abundances. The recorded species are listed in Table 6.

[4] Ben Mustapha K., Komatsu, T., Sammari, C., Hattour, A., Zarrouk, S. and El Abed, A. (2003). *Posidonia* meadows from Messioua bank (Tunisia). Contribution to the: 3rd Tunisia–Japan Symposium on Science and Technology (TJASST03). Tunis, April 2003. (submitted)

Table 6. Hydrozoan, madreporian, sponge, ascidian and bryozoan species recorded on the Banks off the coast of Zarzis

Taxonomic group	Species	Remarks
Hydrozoans	*Plumularia setaces*, *Halycordyle disticha*	
Madreporians	*Balophyllia europea, Cladocora cespitosa*	
Sponges	Order Dictyoceratida: *Hippospongia communis, Spongia officinalis, S. nitens, Cacospongia mollior, Fascispongia cavernosa, Ircinia fasciculata, I. spinosula, I. chevreuxi, Sarcotragus muscarum*. *Dysidea fragilis*	
	Oscarella lobularis, Cliona viridis, C. celata, Chalinella sp., *Crambe crambe, Anchinoe tenacior, Hemimycale columella, Hamigera hamigera*	
	Petrosia ficiformis	deep area: at 30 m. depth
	Verongia aerophoba, Chondrilla nucula	Very rare
	Tethya aurentium, T. citrinae, Geodia cydonium	Absent or recorded only on Ras Dzira
Ascidians	*Aplidium* sp., *Pseudodistoma* sp., *Didemnum* sp., *Diplosoma* sp., *Polycitor* sp., *Clavelina* sp., *Ecteinacidia turbinata, Botrylloides* sp.	
Bryozoans	*Pentapora fascialis, Raptedeonella* sp., *Sertella septentrionalis, Schizoporella* sp., *Margaretta* sp.	

The sponge population of Messioua comprises 29 common species showing a varying density. For instance, the density range for species of the Order Poecilosclerida is 0.4–2.4 individuals/m², while species of the Order Dictyoceratida have a density range of 0.13–3 individuals/m², which is higher than that of the Salakta sponge beds (Rützler 1976).

Data on Messioua Bank for August 2001 were obtained by scanning *Posidonia* meadows with a multi-beam sonar SEBAT 9001 (Reason and Co.) which can emit several decadal beams from the transducer, to measure not only the bottom depths but also the height distribution of the seagrass beds (Komatsu *et al.* 2001). We tried to harmonize these data from field-truth campaigns (October, 2000; May and August, 2001). The analysis of the first data set, relating to the density as well as the richness of the sponge population, showed no correlation with the values of the *Posidonia oceanica* density (in shoots/m²). Nevertheless, such a correlation may exist only for the commercial sponges of the Family Spongiidae (*Hippospongia communis, Spongia officinalis, S. nitens* and *S. virgultosa*), whereas all other representatives of the Order Dictyoceratida (e.g. *Sarcotragus muscarum, Ircinia fasciculata* etc.) do not show such a correlation.

These field campaigns were also an occasion to note the presence of a disturbed biota on the El Biban Bank (off El Bibane Lagoon), and on another off the coast of Zarzis, where sponges of the Order Dictyoceratida show evidence of disease.

Finally, two algae, both recorded on the Messioua Bank, are listed for the first time:

Caulerpa racemosa, at 24 m depth, covering the detritic substratum produced by the burrowing sponges *Cliona celata* and *C. viridis*. The same biota was also recorded for *Caulerpa racemosa* at several stations off Cap Bon (see above), where the alga was always present near these burrowing sponges and at a depth of 45 m; off the south-eastern coast of Kerkennah Island (Ben Mustapha and El Abed 2001), as well as in the Gulf of Gabès (Hamza *et al.* 1995).

Halymenia dichotoma (Rhodophyceae: Grateloupiacea), at 21 m depth in the precoralligenous assemblage of the circalittoral enclave of *Posidonia* rhizomes. Referring to the review of Ben Maïz (1995) of the Tunisian marine macroalgae, and to Boudouresque (1997), this would appear to be the first record of a species of the *Halymnia* genus in Tunisian waters.

4. Discussion and conclusions

This review of some examples of sessile benthic species from the main macro-benthic assemblages along the Tunisian coast shows that they are not suffering from the impact of human activities. This is especially the case for the Tunisian islands and banks. This brief review was also an occasion to update the list of macrobenthic sessile species in some areas.

However, a few sites showed a slightly disturbed benthic marine environment, while others presented a more disturbed biota, such as the meadows off Sousse and Monastir. The remaining sites of the Gulf of Gabès (El Abed and Hattour 1997; Hattour *et al.* 1998; Ben Mustapha *et al.* 1999) and the coastal detritic biota of the Gulf of Tunis have undergone major changes in their macrobenthic assemblages which could rapidly lead to the establishment of a muddy-bottom biota.

In 1999, the coralligenous biota of some sites, mainly around Cap Bon, underwent significant degradation of some assemblages, owing to massive mortality of their gorgonian representatives. This was supposed to be due to the persistently high temperature in the whole water column down to 60 m depth (Ben Mustapha and El Abed 2001), without either the seasonal thermocline, usually at 20 m depth, or the strong vertical temperature range (10°C; Sammari *et al.* 2001). Nevertheless, prospections carried out in 2000 and 2001 showed a good recovery of these biota.

Other sites, where both *Caulerpa racemosa* and *C. taxifolia* were recorded on a very strong coralligenous assemblage down to a depth of 46 m, show how fast these two species of *Caulerpa* might adapt to new biotic conditions.

We would submit several recommendations to the consideration of the present expert consultation:

- To harmonize data collection and management and delimit the geographical area of the project
- To list all the benthic species/habitats of the area
- To conduct more-specific quantitative studies of the population structure of the main benthic groups (since they are the only tool for studying the impact of human activities on benthic habitats)
- To conduct specific quantitative studies of the sponge population structure at the Tunisian–Libyan border, since the sponge stock is shared there
- To support a standardized scientific assessment of the red coral population in the area
- To conduct specific studies on the coralligenous habitats in the MedSudMed Project area

- To conduct specific quantitative studies of the *Posidonia oceanica* meadows in areas where data are not up to date or do not exist, and to conduct comparative studies in the area.

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The HRPT station at IRMA–CNR in Mazara del Vallo for the acquisition and analysis of satellite data in the Strait of Sicily

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Abstract

The satellite data receiving station recently installed at IRMA–CNR is presented. It consists of a set of hardware and software and receives visible and infrared images from NOAA and ORBVIEW satellites. The images are received (NOAA and SeaWiFS) with a resolution of 1 square kilometre. The institute is currently developing treatment protocols for the image processing according to the use the images are destined for. A review of the remote-sensing applications is made for different fields of research and management. A focus is made on the study of the Strait of Sicily where the objective is to connect the knowledge on physical environment to information provided by remote-sensing data. Future application would be to use parameters such as temperature and ocean colour of the sea surface to monitor and forecast the biological productivity of the water column and ultimately the state of the fishery resources.

1. Remote sensing of the Strait of Sicily at IRMA–CNR in Mazara del Vallo

The HRPT–LAC (high-resolution picture transmission–local area coverage) receiving station was installed at IRMA–CNR (Institute of Research on Marine Resources and Their Environment, of the National Research Council) in Mazara del Vallo with the objective of obtaining satellite data and infrared imagery by remote-sensing monitoring of the Mediterranean basin and the Strait of Sicily.

Since May 2002, IRMA–CNR has been one of 128 authorized NASA research stations for SeaWiFS high-resolution LAC data (IRM, Serial no. 2082, Mazara del Vallo).

Another authorized station is MLT at the University of Malta, Euro-Mediterranean Centre on Insular Coastal Dynamics. These two stations can collaborate to develop joint research on the description and analysis of the physical environment of the Strait of Sicily by remote sensing.

IRMA–CNR submitted the "Letter of Agreement for SeaWiFS Direct Readout Ground Stations" and obtained from NASA an agreement that temporarily enables a non-real-time SeaWiFS HRPT station to decrypt real-time data and release it to authorized users , under a research project denominated "Analysis and forecasting system of the fishing fleet in the Strait of Sicily based on satellite SeaWiFS data."

The IRM SeaWiFS HRPT station, after a testing and validation period, has been operational since November 2002 and has collected some images from satellites NOAA 12, NOAA 14, NOAA 15, NOAA 16, NOAA 17 and ORBVIEW-2/SEASTAR.

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2. General description of the IRM–HRPT station

The receiving station (HRPT IPLASAT PC-1800) is of the automated HRPT type and currently receives visible and infrared images from AVHRR sensors on NOAA and ORBVIEW satellites. It consists of a set of hardware and software which includes the orbit calculation programmes, the visualization programme, the power system for dish movement, the microprocessor systems to receive the radio-frequency signal, to transform it into a digital signal and to memorize it on disk.

It is a completely modular system with different possible configurations. While the receiver works for NOAA, ORBVIEW-2/SEASTAR, it also monitors the Russian meteorological satellites (COSMOS, METEOR, OKEAN), the Chinese satellite (FENG YUN) and those of METEOSAT. The OKEAN data acquisition is particularly important because these satellites are equipped with SAR (synthetic-aperture radar).

The station is provided with all the installation equipment and precision mechanics needed for the whole cycle of mechanical processing of the station and thus constitutes a suitable LAC unit. The installed system represents a high-technology system in the fields of mechanics, electronics and computer science. Its highly sophisticated processing packages (ER Mapper, SeaDAS, ERDAS, ARC/INFO, CHIPS, IDRISI and so on) permit the automatic acquisition and memorization of the data transmitted by satellites for the purposes of research and monitoring.

Currently, following the period of testing, the station is used for the reception of the data from satellites NOAA 12, NOAA 14, NOAA 15, NOAA 16, NOAA 17 and ORBVIEW-2/SEASTAR.

The next objective of the Remote-Sensing Group at IRMA–CNR is to upgrade the station to assure the reception of data from the IKONOS, MODIS, ENVISAT and LANDSAT satellites.

All the received images and data are stored in a data base that will be available online with a view to allowing rapid consultation of the data and the use of the images by other research centres.

3. Image analysis and processing

At the moment, the station is equipped for the reception of NOAA and SeaWiFS images. The spatial resolution (the smallest area on earth distinguishable by a satellite's instruments) of these satellites is 1 square kilometre. The on-board sensors record the emission or reflection of electromagnetic waves from objects on earth at different frequencies. What we see as an image is actually a representation of the recorded radiation values. The information content is therefore far greater than that given by simple photography. Particularly, the NOAA satellites transmit in five wave bands, while the SeaWiFS transmits in eight bands (from the visible to the infrared) plus telemetry data. In any case, each received image needs to be processed and the number of treatments depends on the utilization the image is destined for. Typical treatments are geo-referencing, geometric corrections, light corrections, atmospheric-effects corrections and noise reduction. One of our main targets is to create a protocol and some

patterns for the image processing in relation to various classes of homogeneous projects (creation of experienced systems for image processing).

The NOAA advanced very-high-resolution radiometer (AVHRR) covers very large regions of the earth with a high spatial resolution (about 1 km) relative to the area covered (hundreds of thousands of square kilometres).

The remote-sensing applications range from cartography to defence to natural-resource studies. The remote sensing of ocean colour from space provides information on the abundance of phytoplankton and the concentration of dissolved and particulate material in ocean surface water. This information can be used to investigate biological productivity in the oceans, marine optical properties, the interaction of winds and currents with ocean biology and how human activities influence the oceanic environment.

In the field of integrated coastal-zone management, the following applications are particularly interesting:

- geo-referencing by GIS
- chlorophyll maps
- temperature maps
- suspended-solid maps
- monitoring of eutrophication.

These data might help to monitor processes like cliff erosion, land-use changes, urban development and the changes in the natural vegetation patterns. Other interesting applications in the environmental sphere, such as the creation of land-coverage maps or the prevention of natural disasters, require the reception and utilization of images with a greater spatial resolution (from 200 m to 10 m), but our station is not yet qualified for that.

4. Main target of research: the Strait of Sicily

The main object of study will be the Strait of Sicily, with the purpose of integrating the knowledge of the physical environment of the region (hydrographical characteristics, bathymetry, sedimentogy, habitat mapping, bottom topography of the fishing grounds) with that furnished by the remote sensing.

The Strait of Sicily connects the two main basins of the Mediterranean, the western and the eastern. At its narrowest point, between Cape Bon (Tunisia) and Mazara del Vallo (Sicily), the Strait is about 130 km wide. It is characterized by a two-layer flux model, like the Strait of Gibraltar. The upper layer, called "Modified Atlantic Water" (MAW), is identified by water with a relatively low salinity flowing from the western towards the eastern basin. The lower layer, called "Levantine Intermediate Water" (LIW), is identified by water with a relatively high salinity flowing in the opposite direction, like an undercurrent.

The complex bathymetry influences the features of the currents in the region. A bottom ridge in the middle of the Strait divides the flow into two parts: one along the Sicilian shelf, which is narrow and deep, the other off the Tunisian coast, which is wide and shallower. Astraldi

and colleagues showed that these two parts have two different flows, for the MAW and for the LIW. Measurements have shown that the mesoscale signal prevails in the upper layer, with the presence of eddies and meanders.

According to Robinson and his co-workers, the MAW motion, called the "Atlantic-Ionian Stream" (AIS), has quite a steady mean path. It enters the Strait from the western side along the Adventure Bank (south-western shelf of Sicily), coming close to the Sicilian coast in the middle of the south coast of Sicily (the deep Gela Basin) and separates again when it encounters the Malta Bank (south-eastern shelf of Sicily).

The AIS encircles two large cyclonic meanders, identifying two sectors, one around the Adventure Bank on the western side, the other around the Malta Bank to the east.

An analysis of the SST, which affects the survival/mortality rates in the early life stages of red mullet, influencing the strength of recruitment at two sites, can be carried out using satellite imagery, in connection with studies on the phenomenon of upwelling.

5. Other fields of research

The relationship between the biological and physical phenomena of the sea is of great interest and the object of study for potential applications, as for instance that of a good knowledge of the state of the resources of the sea (with the possibility to effect assessment and forecasting). This type of information is very useful in the fishery and aquaculture sectors. The use of the techniques of remote sensing as a means of locating populations of pelagic species has been hypothesized since the appearance of the first airplanes.

The best sea parameters observable from space are the temperature and colour of the sea surface: they can be used for the identification of specific currents and the classification of water bodies. The first attempt at aerial observation was in 1970 with measurements of spectral radiance to calculate the concentration of chlorophyll. During the last 30 years, the technology of remote sensing has greatly improved, putting the problem of its use in support of fisheries in evidence. It is not possible to observe a shoal of pelagic fish directly by remote sensing from space. The most appropriate way to use remote-sensing data is to connect the observable physical parameters with the presence of fish species. These relationships must be defined both from theoretical (or empirical) relationships and from "ground-truth" observations. A typical example is the sea areas characterized by upwelling, in which, as a rule, prevailing winds, combined with Coriolis' force, pushes coastal surface water towards the open sea, the consequent deficit being met by deeper and colder water rich in nutrients. These areas of upwelling are among the richest in nutrients and where the greatest quantity of pelagic resources is found. These areas are also in many cases (especially in summer) observable by satellite radiometers both by the presence of colder water and the distinctive colour which therefore serves as a tracer.

A fundamental problem is the location of the areas of high primary productivity and the discrimination of the relationships between the productivity and the observable parameters (colour, temperature and chlorophyll). In view of the objective to evaluate the distribution of the areas of higher than average abundance of marine resources, especially from space remote-sensing data, their spatial and temporal distribution are more important than the absolute value of the biological variables (particularly of the primary productivity). Primary

productivity is correlated, even if only approximately, with the biomass of phytoplankton and can therefore be determined. The photosynthetic pigments of the phytoplankton, especially in the open sea, are the principal modulator of the colour of the sea as observed from space.

Thus from the space observation in the visible spectrum it is possible to correlate certain parameters with the biological productivity, such as the phytoplankton biomass or the chlorophyll concentration (i.e. ocean colour); this has proved to be of fundamental importance in the evaluation of marine biological activity.

The sea-surface temperature is another fundamental indicator, correlated with the ocean dynamics as a major factor in the determination of the thermal gradient and the formation of thermal fronts. In some cases it is used for differentiating pelagic species, based on the fact that certain species have a specific temperature preference and that a direct correlation between the presence of certain species and the temperature gradient exists.

The application potential of these observations is resumed in the possibility of analysing and, in some cases, forecasting the state of the fishery resources and their spatial and temporal distribution.

The sea-surface temperature, in addition to being the parameter most easily observed from a satellite, is also recognized as an indicator, with considerable direct and indirect effects on marine plants and animals, since these have the tendency to move within certain temperature ranges and along thermal fronts, depending on the species.

At IRMA–CNR, with the HRPT receiving station, it will be possible to develop new lines of research in the followings fields:

- seasonal and interannual variability of the SST field in the Strait of Sicily
- integrated study of sea-level anomaly, ocean colour and SST mesoscale dynamics in the Strait of Sicily, based on satellite data.