Pisa
18-21 March 1998

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Demersal resources in the Mediterranean

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Ifremer

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Proceedings of the Symposium
held in Pisa, 18-21 March 1998

Ifremer

Proceedings of the symposium on Assessment of demersal resources by direct methods in the Mediterranean and the adjacent seas

Pisa (Italy), 18-21 March 1998

The symposium was organized under the auspices of the following bodies:
the Centro Interuniversitario di Biologia Marina di Livorno (CIBM, Italy),
the French Research Institute for the Exploitation of the Sea (Ifremer, France),
the Italian Society of Marine Biology (SIBM, Italy),
the National Centre for Marine Research (NCMR, Greece),
the Spanish Institute of Oceanography (IEO, Spain),
the University of Pisa (Italy).
with the support of
the Direzione Generale della Pesca e dell'Acquacoltura (Italy),
the European Commission (FAIR MAC/08/97).

The symposium strongly benefited of the partnership developed since 1994 through the MEDITS programme which involved the following partners:
the Agenzia Regionale Protezione Ambientale della Toscana ARPAT (ex CRIP) (Livorno, Italy),
the Centro Interuniversitario di Biologia Marina (CIBM, Livorno, Italy),
the COISPA Tecnologia Ricerca (Molo di Bari, Italy),
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Foreword

Thank you for your kind invitation to participate in this meeting aimed at establishing the advances made in MEDITS*. Unfortunately Eurocrats often have other obligations certainly less noble than scientific debates, and for this reason Antonio Cervantes, who is from now on responsible for the studies in support of the Common Fisheries Policy, will replace me. The purpose of this note is to let you know how DG XIV sees the evolution of the MEDITS programme, as requested by Jacques A. Bertrand. Antonio will be able to transmit our views and to obtain your impressions and suggestions.

First of all I would like to underline our satisfaction with the way in which your work is progressing and that your meetings are so open and constructive. We are particularly happy because your work is essential for the implementation of rational management of our Mediterranean fisheries and because the importance of the Community budget devoted by DG XIV to MEDITS deserves our closest attention.

It is of course too early to reach firm conclusions, but we are convinced that the dynamics of the programme are already a success having regard to the enthusiastic attitude of the current participants and the desire of other teams to join this venture.

I have to admit that initially I had the worry that historic barriers could not be overcome. This could have led to a lack of standardization and thus to a programme in which results would not have been compatible spatially or temporally. I am pleased to see that great effort has been devoted to the question of standardization and that this will be one of the subjects addressed in the meeting. I also had the fear that the "Mediterranean syndrome" would have prevented free exchanges with scientists working in other fisheries. Once more I have to congratulate you for having opened the meeting to colleagues from other fisheries.

A second concern was the processing of the information obtained. I was worried that each team would try to create an original algorithm without seeking a total compatibility of tools and procedures. Even though a unique database is not necessary, MEDITS would loose part of its meaning if it did not implement a common pool of standardized data open to those who could make full utilization of it, starting with the main participants. I am pleased to note that the question of interfaces will be addressed. I cannot stress enough how we continue to be preoccupied with this problem. In other words I am only partially reassured.

Another important question is the final utilization of the information collected. I am pleased to note that intense work is being undertaken for the exploitation of data. I believe in the usefulness of all the cartographic work which is being developed, but I would like to encourage you to quickly advance towards the essential goal of MEDITS: the scientific advice for fisheries management. I have the feeling that further progress is needed before your work can be incorporated into the decision-making process.

* International bottom trawl survey in the Mediterranean.

Finally, I know that you wish to have DG XIVs feelings about the future of MEDITS. Actually I would like to assure you that we are convinced of the progress made and that we are anxious that these benefits are not wasted by abrupt decisions. MEDITS is a base on which to further build a global Mediterranean scale and is a good example to be followed by your colleagues from outside EU. We are interested in continuing supporting your work but budgetary uncertainties do no allow us to make promises. It is not possible, anyway, to provide mechanical support year after year to the current surveys. The future of MEDITS depends on the definition of a global strategy to collect the information needed for management purpose. Such a strategy could ideally be harmonized within the newly created Scientific Committee of GFCM* with data collection plans defined outside the EU. If this strategy is missing, the usefulness of MEDITS could be limited, as I already underlined in our meeting in Paris in autumn 1996. Taking into account that the methodology has been implemented and standardized, the frequency of the trawling surveys should be reduced. A frequency between two and four years would be enough. In fact it is not necessary to systematically assess the stocks as the decision-making process is not based on annual TACs. However, the evolution of the abundance and of the exploitation rates on a midterm basis have to be defined to, if necessary, adjust fishing effort. Effort management has been recognized as the most appropriate approach for the Mediterranean fisheries within the EU, and this has been confirmed by GFCM. But such a management system also requires continuous effort monitoring. Furthermore the sampling of commercial catches is indispensable for the estimation of fishing mortality, for debating technical measures and to prepare bio-economic estimations. On this matter the MEDLAND project is a welcome initiative to be co-ordinated with survey data.

I would like also to draw again your attention on the fact that the utilization of logbooks and sales notes is to become compulsory by the beginning of next year and that position control through satellites tracking will progressively increase. Although you should conceive data collection systems for scientific objectives, an increasing synergy with administrative data has to be developed. In certain Member States this synergy has been demonstrated to be very efficient.

In conclusion I would say that a lot of work has been done but more is still to be implemented and that the future of MEDITS depends on the definition of a global strategy. Although we cannot guarantee in the future the continuation of a community grant, you may be sure that we will try our best to support your work, which is in our opinion indispensable. Thank you very much for your work and best wishes for future efforts.

Alain Laurec
European Commission, Director

* At present the European Commission is trying to reinforce GFCM.

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Chapter IV - Spatio-temporal distribution

Chapter V - Species composition

These proceedings are completed by selected papers published in Aquat. Living Resour., 12(3), 1999.

Chapter I

Trawl survey programmes

The International Bottom Trawl Survey in the North Sea, Skagerrak and Kattegat: a history of one of the "ancestors" of MEDITS[1]

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Abstract

Since its start in 1966 as "a pilot-study for future young herring research in the North Sea", the International Bottom Trawl Survey has been conducted annually, and evolved from a specific herring recruit survey into a much more general 'fish survey'. The survey provides primarily information which is used by ICES stock assessment working groups and which consists of abundance indices for recruiting year classes of several commercial fish species and data used for tuning the VPA. In addition, the results are used in a wide variety of studies, varying from investigations of the changes in growth and maturity of certain species, to studies into the ecosystem effects of fisheries.

The paper describes the history of the survey, its current objectives and methods, and the use that is made of the survey results, both in assessments and in the study of the ecosystem effects of fishing.

Introduction

The first internationally co-ordinated research vessel trawling surveys in the North Sea, that formed the basis for the present International Bottom Trawl Survey (IBTS) were carried out in 1960 and 1961 (ICES, 1963). After five years, these international surveys were resumed in 1966 by the Netherlands, and the Federal Republic of Germany (Zijlstra, 1966). In the following years, more countries started to participate, and the survey evolved into probably the largest international fish survey using a standardized gear and methods.

Since many years the results of the IBTS are widely used in the assessments of several North Sea fish species and for various other purposes.

1. This paper is a modified version of a paper which was presented at the ICES Annual Science Conference in Baltimore in September 1997 and which was titled: The International Bottom Trawl Survey in the North Sea, the Skagerrak and Kattegat, by Heessen H.J.L., Dalskov J. & Cook R.M. (ICES, CM 1997/Y:31).

This paper describes the history of the survey, its current objectives, and the methods applied. The results are still mainly used in the assessments of a number of commercially important North Sea fish stocks, in the tuning of the VPA and to derive recruitment indices. The survey results are increasingly used in other studies such as the study of the ecosystem effects of fishing.

The North Sea and its fishery

Because the area which is covered by the IBTS is quite different from the area dealt with in this symposium, a short description of the North Sea and its fishery is given below. This description is mainly taken from Knijn *et al.* (1993).

The northwestern boundary of the North Sea lies along the edge of the continental shelf, west of the Orkneys and Shetlands, whilst the north-eastern margin is formed by a trough, the Norwegian Deep, with a depth of up to 700 metres. The North Sea is connected to the Baltic by the Skagerrak and Kattegat and has a southerly connection with the Atlantic by way of the English Channel. It is a relatively small basin, with a surface area of about 575,300 km^2, and a volume of 42,300 km^3. The total surface of the Mediterranean is much larger (2,966,000 km^2), but here the continental shelf itself is very narrow, or even non-existent. Compared to the Mediterranean, the North Sea is rather shallow; the mean depth ranges from about 30 m in the southeast to 200 m in the northwest. The North Sea is influenced by the Atlantic Ocean, mainly by input from the north but also, to a lesser extent, *via* the English Channel. To the northwest of the British Isles, a strong Atlantic current flows north along the edge of the continental shelf. Several currents bring Atlantic water into the northern North Sea, with one current entering the Norwegian Deep.

The Skagerrak can be regarded as a transition area between the North Sea and the Baltic and has an average depth of 210 metres. In contrast, the Kattegat is rather shallow, with an average depth of only 23 metres.

The North Sea is a highly productive area. The total amount of fish landed from the North Sea increased from one million tonnes at the beginning of this century to two million tonnes in 1956, with marked interruptions caused by the two World Wars. In the late 1950s, landings declined slightly to 1.5 million tonnes, but there was a pronounced increase in the early 1960s. For a decade, landings fluctuated between 3 and 3.5 million tonnes but in recent years they have decreased to 2.5 million tonnes.

The landings of fish can be split into demersal and pelagic species landed for human consumption, and fish used for reduction to fish meal and fish oil (the industrial fishery). The most important demersal species for human consumption are the gadoids: cod *(Gadus morhua)*, haddock *(Melanogrammus aeglefinus)*, whiting *(Merlangius merlangus)*, saithe *(Pollachius virens)*, and the flatfish species: plaice *(Pleuronectes platessa)* and sole *(Solea vulgaris)*. The main pelagic species for human consumption are herring *(Clupea harengus)* and mackerel *(Scomber scombrus)*. The landings from the industrial fishery mainly consist of sandeels *(Ammodytidae)*, the small gadoid Norway pout *(Trisopterus esmarki)*, and the clupeoid sprat *(Sprattus sprattus)*. During the last years total landings of sandeels amounted to around one million tonnes, which is approximately 40% of the total landings.

Most species which are mentioned above are caught in significant amounts during the IBTS. Due to the properties of the survey gear, plaice are caught in relatively small amounts, for sole only a few specimens are caught, and sandeels are almost absent in the catches. An overview of the species mentioned, plus their names in French, Spanish and Italian is given in the table.

The most common commercial fish species in the North Sea.

English	Latin	French	Spanish	Italian
Demersal Species				
Cod	*Gadus morhua*	morue	bacalao	merluzzo bianco
Haddock	*Melanogrammus aeglefinus*	églefin	eglefino	asinello
Whiting	*Merlangius merlangus*	merlan	plegonero/liba/sarreta	merlano
Saithe	*Pollachius virens*	lieu noir	carbonero	merluzzo nero
Plaice	*Pleuronectes platessa*	plie	solla/platija	passera
Sole	*Solea vulgaris*	sole commune	lenguado	sogliola
Pelagic Species				
Herring	*Clupea harengus*	hareng	arenque	aringa
Mackerel	*Scomber scombrus*	maquereau commun	caballa	scombro
Horse mackerel	*Trachurus trachurus*	chinchard	chicharo/jurel	suro/sugarello
Industrial Species				
Sandeels	Ammodytidae	lançons/équilles	aguacioso/sula	cicerello
Norway pout	*Trisopterus esmarki*	tacaud norvégien	faneca noruega	-
Sprat	*Sprattus sprattus*	sprat	espadin	spratto

History

In spring and autumn of the years 1960 and 1961, a series of four large international research vessel trawling surveys was organized under the auspices of ICES. The main purpose of these surveys was to map the distribution of juvenile herring in the North Sea and to investigate the links between herring nursery grounds and the adult populations (ICES, 1963).

In the following years, most of the countries participating in the 1960-1961 surveys, continued similar surveys on their own. Meanwhile a "...Working Group, discussing what form a final analysis (of the 1960-

1961 data) should take, concluded that the extent and complexity of the material and the multitude of factors involved in the analysis, made some form of mechanized processing of the data recommendable. The offer of the use of an electronic computor by the English laboratory was gratefully accepted" (ICES, 1963).

Despite this offer, the analysis of the material collected in 1960-1961 was not yet completed in 1965, and in that year the Federal Republic of Germany and the Netherlands decided to wait no longer and to conduct a pilot-study in 1966 "for future young herring research". From that year onwards, these surveys have been conducted annually with the objective of obtaining annual recruitment indices for the combined North Sea herring stocks. Gradually more countries started to participate in the survey, which was named the International Young Herring Survey (IYHS). For the first few years, sampling was restricted to the southern and central North Sea. In 1969, the Skagerrak and Kattegat were also included in the survey area.

Although the emphasis was, from the start of the surveys, mainly on herring (Zijlstra, 1966), also the whiting data collected in the early years have been analyzed (Gambell *et al.*, 1962). In the course of the 1970s it was realised that the IYHS could provide recruitment indices not only for herring, but also for roundfish species such as cod, haddock, and whiting. This growing interest resulted in a northwards extension of the survey area to cover the entire distribution of juvenile haddock in the North Sea, and also that of Norway pout. The whole North Sea, the Skagerrak, and the Kattegat have been surveyed from 1974 onwards, with most hauls restricted to the month of February.

In addition to the IBTS bottom trawl programme, a sampling programme of late herring larvae (6-month-old) was started in 1977. The standard gear which is presently used is a 2 square metre plankton-ringnet, the so-called MIK-net (Method Isaacs Kidd net). Most bottom trawls are taken during the daylight period, whereas fishing with the MIK is restricted to the hours of darkness (ICES, 1996b). The results of this sampling are used as an early indication of year-class strength of herring. This part of the survey will not be discussed in this paper.

During the first years, the surveys were co-ordinated by the ICES 'Working Group on Young Herring Surveys'. A 'Gadoid I-group Working Group' was established in 1976. In 1981 the groups had a joint meeting (ICES, 1981a) where an evaluation was made of the results obtained by the surveys in the preceding years for the seven main species (herring, mackerel, sprat, cod, haddock, whiting and Norway pout). No longer exclusively aimed at herring, the survey was renamed the International Young Fish Survey (IYFS). During the 1981 meeting, the first formal manual of the IYFS was produced (ICES, 1981b). In 1984, it was decided to combine the two Working Groups (herring and gadoids) in the Working Group on International Young Fish Survey in the North Sea, Skagerrak and Kattegat.

In 1990, the IYFS Working Group evaluated the usefulness of a number of bottom trawl surveys in the North Sea, Skagerrak and Kattegat (ICES, 1990). Apart from the IYFS in the first quarter of the year, these surveys comprized of at least seven national surveys, carried out in different quarters. The IYFS WG proposed to combine the IYFS and the national surveys in quarterly co-ordinated surveys in the North Sea, Skagerrak and Kattegat, which were to be called the International Bottom Trawl Survey (IBTS). The immediate reason for co-ordinated quarterly surveys was the so-called North Sea Stomach Sampling Programme scheduled for 1991. Another reason was a more efficient use of ships time. It was recommended that the quarterly surveys should run for a period of five years. These surveys should provide a full description of the seasonal distribution of the stocks sampled, which was considered urgently necessary for the further improvement of multispecies assessments and the development of spatially disaggregated assessment models. Possible continuation of quarterly surveys after five years should depend on an evaluation near the end of the five-year period.

This proposal resulted in a series of six years (1991-1996) with quarterly surveys, which, with a few exceptions, extensively covered the whole survey area in the North Sea and Skagerrak/Kattegat (ICES, 1996a). Since it proved impossible, however, to keep the research vessel effort at this very high level, when at the same time research budgets are decreasing in most countries, the present development seems to be towards an international co-ordinated survey carried out twice a year: once in January/February and in August/September.

Current objectives

The current objectives of the IBTS are:

- to determine distribution and abundance of pre-recruits of the main commercial fish species with a view of deriving recruitment indices;
- to monitor changes in stocks of commercial fish species independently of commercial fisheries data;
- to monitor changes in stocks of species which are currently not of commercial interest;
- to collect data for the determination of biological parameters for the more important species;
- to determine the abundance and distribution of late herring larvae (February survey);
- to collect hydrographical information (temperature, salinity, nutrients).

Generally accepted as the main objective of the IBTS is the provision of recruitment estimates of several commercially important fish species and of data used for tuning the VPA (Virtual Population Analysis). The main users of this information are the ICES Herring Assessment Working Group for the area south of 62° N (herring and sprat) and the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (cod, haddock, whiting and Norway pout).

The information which is collected during the February survey on distribution and abundance of late herring larvae, is used in the herring assessment. For hydrographical research, the February survey provides a unique time series. In recent years, the collection of nutrient data is becoming increasingly important.
In the years 1991-1996, an additional objective was the description of the seasonal distribution of North Sea fish by means of quarterly surveys.

Technical description

As an important part of the standardization and quality assurance of the survey a manual has been written. The first edition of which was discussed and agreed in 1981 (ICES, 1981b). The fifth revision of the Manual was published in 1996 (ICES, 1996b). This manual provides guidelines for all aspects of the survey, including a description of the gears used, fishing method, data to be collected, data exchange formats, etc.

Survey gear

During the early years of the survey, a commercial 78-foot Dutch herring trawl was recommended as the standard gear. This gear, however, could only be operated from side trawlers and not from stern trawlers. In 1977, it was therefore decided to choose the GOV-trawl as standard gear for future surveys (ICES, 1977), a gear which was considered to be relatively easy to handle. In 1978, four vessels started using the GOV-trawl, but it took some years before the new standard gear was fully implemented.
The GOV-trawl (chalut à Grande Ouverture Verticale) is a French-designed trawl, with a high vertical net-opening of five to six metres. The horizontal opening of the trawl is approximately 20 metres. The standard sweeps used measure 60 m, but when the water is deeper than 70 m longer sweeps (110 m) are used. The distance between the trawl doors varies from approximately 70 m in shallow water to about 120 m in the deeper parts of the North Sea. The mesh size decreases from 100 mm at the mouth of the net to 10 mm (16 mm stretched mesh) in the codend.
Although the GOV-trawl was adopted as the standard gear for the IBTS, and a detailed specification of the net is given in the survey manual, in practice the nets used by individual vessels are all slightly different. This is mainly due to different interpretations of the net drawings and to differences in the way the nets are rigged.
Standardization of the rigging of the GOV-trawl, and of the fishing method, is an item which is discussed at almost every meeting of the IBTS Working Group. In 1984, a meeting of a number of research vessels was organized in Hirtshals during the IBTS in February, where flume tank trials of a model of the GOV-trawl were conducted in the North

Sea Centre (Wileman, 1984). Also the ICES Fishing Technology and Fish Behaviour Committee discussed the GOV-trawl in great detail. In 1992, a report was produced by a subgroup of this committee, which tried to evaluate the sources of variability in the fishing power of the GOV-trawl (ICES, 1992b).

Several other studies on the performance of the GOV-trawl have been published, (Galbraith, 1986; Stewart & Galbraith, 1987; Hagström, 1987; Ehrich, 1987; Newton, 1989).

One of the factors which may influence the catches of the various vessels which participate in the survey is the length and type of small-meshed lining of the codend, which in 1992 appeared to vary from country to country. After years of standardization, differences appeared to exist in the interpretation of this part of the gear description (ICES, 1992a). Some countries used a codend lining as described in the Manual, other countries just used a fine-meshed codend. Sweden used a small meshed codend of extra great length to be sure to sample sprats efficiently. The influence of these differences on the catch rates have never been systematically analyzed, and thus no correction can be applied. The influence of such differences may not be very significant, as long as there are no major changes in the allocation of the different vessels over the survey area. Gradual changes in allocation have, however, occurred in the course of the years.

Another difference between the GOV-trawls used by different vessels which may be important is the extent to which bobbins have been (and still are) used on rough grounds. Although the Manual strongly recommends that the standard groundrope, consisting of rubber discs with a diameter of 10 and 20 cm, should be used throughout the survey area, bobbins have quite often been used to reduce gear damage. Trawls fitted with bobbins are shown to catch fewer small fish than those with the standard groundrope, because small fish may escape underneath (Engås & Godø, 1989; Ehrich, 1991).

Although a standard gear was accepted in 1977, discussions on the correct and internationally accepted interpretation of the description of the net are still continuing, *e.g.* on the number of meshes of certain panels of the net, and the weight and length of certain components of the groundrope. Another point is whether to use a standard Exocet kite as prescribed in the Manual, or just a simple wooden board with a float, or no kite at all.

Other complications with respect to the gear were introduced when different national surveys were combined into quarterly surveys in 1991. Some of these national surveys (the English and Scottish Groundfish Surveys) had already a long history, and used other gears than the GOV-trawl. England used a Granton trawl during their third quarter survey, but switched to the GOV-trawl in 1992. Conversion factors are applied to allow the whole time series from 1977 onwards to be used. Scotland still uses an Aberdeen trawl during their third quarter survey. It will therefore be difficult to incorporate the results of the Scottish catches properly in overall IBTS quarter 3 indices. A bobbin gear is used and the mesh size of the codend is considerably greater than the mesh size of the GOV: 35 *versus* 20 millimetres. An unknown part of the small fish are not caught at all by the Aberdeen trawl, and conversion of Aberdeen trawl catches into GOV-trawl catches for these small fish will not be possible. It is likely that Scotland will switch to the GOV when the present R/V *Scotia* is replaced later this year. This should greatly improve the total international dataset collected during the third quarter.

Survey design

The stratification of the survey has always been based on the grid of so-called ICES statistical rectangles (one degree longitude x 0.5 degree latitude ≈ 30 x 30 nautical miles ≈ 56 x 56 km). Each rectangle is usually fished by the ships of two different countries so that at least two hauls are normally made per rectangle (plus, ideally, at least two plankton hauls with the MIK-net).

The design of the quarter 1 survey has gradually changed over the years. In 1974 the survey was still very much a herring survey (ICES, 1974). In that year it was decided to use three strata which depended on the amount of herring caught in former years: stratum 1 with the lowest catches consisted of 35 rectangles in which 2 hauls per square should be made, in stratum 2 (12 squares), 6 hauls should be made per square, and stratum 3 where the highest catches of herring were made consisted of 6 squares in which 12 hauls should be made. Per stratum this would result in a total of 70, 72 and 72 hauls respectively. After some years this system was dropped and for several years 4 hauls per rectangle were to be made in the southeastern North Sea, the most important area for juvenile herring (between 53°30' and 57°N, and 4° to 8°E), and 2 hauls per rectangle in the remaining area. In 1991, at the start of the quarterly surveys, part of the research vessel effort from quarter 1 was shifted to other quarters and from that year on the target was to make at least 2 hauls per rectangle in the whole survey area.

A typical allocation of the different vessels during the quarter 1 survey is shown in figure 1.

This allocation has also changed slightly over the years. The latest main reallocation occurred in 1991, but it was then tried to keep at least one vessel in every sub-area which had fished there over most of the recent years. An example of the actual fishing positions and coverage is shown in figure 2.

For the other quarters, three different grids were introduced (ICES, 1990): the 'coarse grid' based on the routine in the English Groundfish Survey which covers half of the rectangles in the North Sea (fig. 3), the 'complementary coarse grid' covers the other half, and a grid that consists of all neighbouring rectangles in a certain area (as used for example in the Scottish Groundfish Survey). The idea was that in every quarter at least 4 vessels should participate: one vessel fishing the coarse grid, one the complementary coarse grid, one should fish all rectangles in the southern half of the North Sea and one in the northern half.

Figure 1
Example of vessel allocation used during the quarter 1 IBTS in 1998.
Each rectangle is fished by two countries:
D Denmark, F France,
G Germany, NE Netherlands,
NO Norway, S Scotland,
SW Sweden.

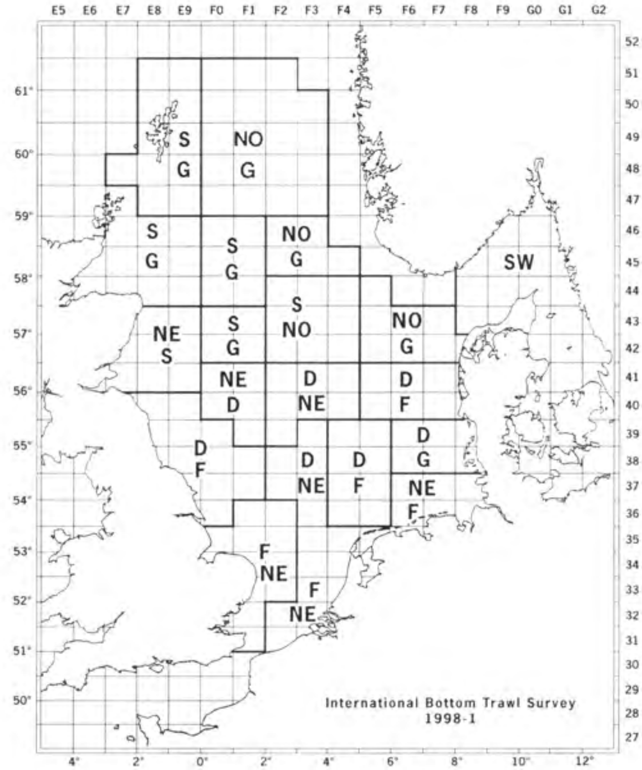
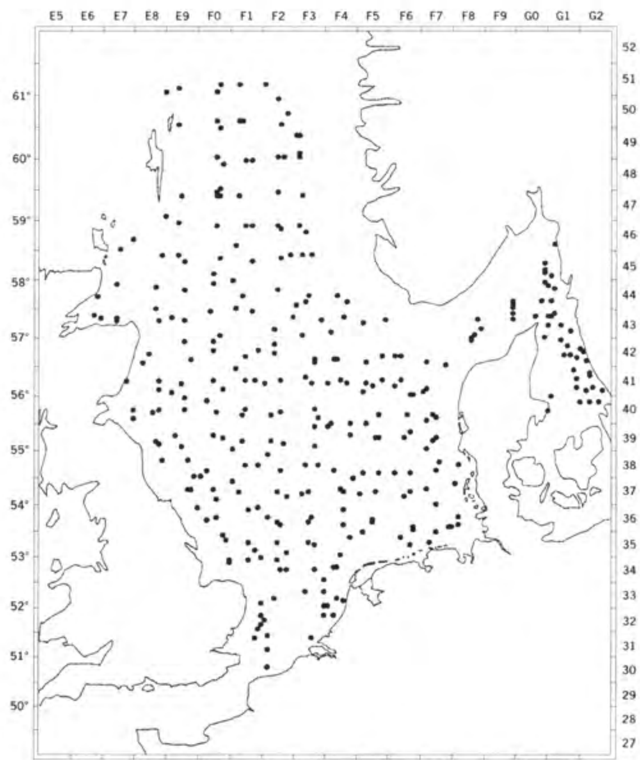


Figure 2
GOV fishing positions during 1995 quarter 1 IBTS survey.



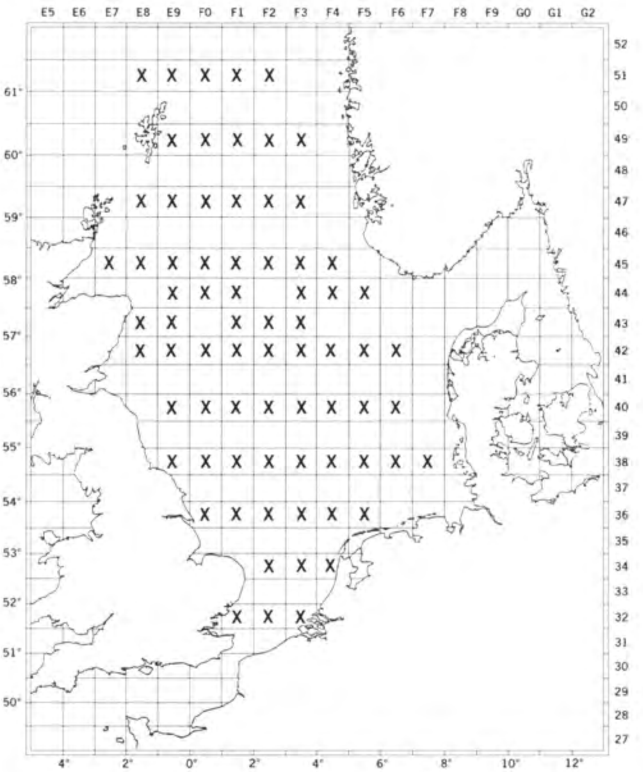


Figure 3
'Coarse grid' as one of the station grids suggested for the quarterly surveys.

In this way all rectangles should be fished twice, by two different vessels. It was also envisaged that all data from a certain quarter could be combined into one overall abundance index, but that time series of abundance indices for one vessel consistently fishing a certain area could also be used independently.

Survey frequency, participation and co-ordination

The first quarter IBTS has been conducted each January/February since 1966. From 1974 onwards the whole North Sea, Skagerrak and Kattegat have been covered, except the parts deeper than 200 m which form the northern limit of the North Sea, and the Norwegian Deeps. During the MEDITS surveys, hauls are made in much deeper waters, up to a depth of 800 m (Bertrand *et al.*, 2000). From 1991 to 1996, the IBTS survey was held on a quarterly basis. From 1997 the survey is carried out twice a year: in quarters 1 and 3. The catches during these two quarters reflect the different fish compositions in winter and in summer. In summer a significant increase in the amount of fish can be observed, due to the immigration of mackerel and horse mackerel *(Trachurus trachurus)*, both from the south and from the north.

With the exception of Belgium, all countries bordering the North Sea participate, *i.e.*: France, England, Scotland, Norway, Sweden, Denmark, Germany and the Netherlands. From 1971 to 1982 also the former USSR participated in ten surveys.

The surveys are co-ordinated by the IBTS Working Group which usually meets every two years. In each of the countries which participate in the survey there is one so-called 'national IBTS contact person', who can be approached by the chairman of the Working Group and who is responsible for distributing important information concerning the survey to his colleagues.
The chairman of the Working Group has, so far, always been responsible for the co-ordination of the quarter 1 survey. Other members of the group were responsible for the surveys in each of the other quarters, but since these have been almost completely reduced to quarter 3, there are only 2 co-ordinators left. The co-ordinators should try to take care that the whole survey area is covered (and especially undertake action in case one of the vessels has for example engine or other problems). The co-ordinators should also collect and distribute preliminary catch data.
In 1994 the area of responsibility of the IBTS Working Group was extended, and the WG now also co-ordinates surveys in the area to the west of the British Isles, France, Spain and Portugal, all along the continental shelf from the Hebrides to Gibraltar (ICES Sub-Areas VI, VII and VIII, and Division IXa). For this large area, two area co-ordinators have been appointed, one for the northern part, and one for the southern part.

Fishing positions and fishing method

Within the rectangles allocated to them, vessels are free to choose fishing positions. Fishing should not be influenced by shoals located by sonar or echo sounder. For practical reasons, to minimize damage to the trawl, vessels are encouraged to use positions from a list of clear tow data which has been assembled over recent years.
The problem of using fixed stations instead of the procedure used at present has been raised several times. In 1990 the WG recommended the use of a fixed station scheme within rectangles, thus accepting non-random haul allocation within rectangles. Because most vessels choose between a limited number of trawl tracks within each square the present procedure is called semi-random.
An analysis to find out whether or not the practice of choosing fishing positions within a specific rectangle has changed over the years in individual countries shows that considerable differences can be observed, both between countries and between periods (Heessen *et al.*, 1997). In the most recent period (after 1990), some countries (Scotland and Denmark) choose their fishing positions less in agreement with the 'fixed station' idea than others. Countries like England, the Netherlands and Germany appear to have altered their sampling strategy more towards 'fixed stations' as compared to the period 1985-1990.
Initially one-hour hauls were made, but because of the large catches in the early 1970s it was decided to standardize haul duration to 30 minutes. The Scottish vessel, however, has continued to make one-hour hauls. Start of a haul is defined as the time when the vertical net-opening and doorspread are stable at a trawl speed of four knots. Stop

time is defined as the begin of pull back. It is encouraged that vertical net-opening and the distance between the trawl doors is recorded during each haul.

Because of the behaviour of herring, it is preferred that fishing, especially in quarter 1, should only be made during daylight hours. Initially a limited area was defined as the herring standard area (figure 6.4 in ICES, 1996b), and in this area fishing should be made during daylight hours only. Since 1993 this limited standard area is no longer used for the calculation of the herring abundance index, but the total survey area is used instead. Therefore, it is now recommended, that all trawling in quarter 1 should, as far as possible, be limited to daylight hours. Night hauls are excluded from the index calculation for herring, but they are still used for all other species.

Standard hydrographic data collection

At each trawl station, the minimum hydrographical data to be collected are temperature and salinity at surface (5 m depth) and at the bottom. Since 1992 other information, such as surface and bottom current direction and speed, swell height and wind speed, etc., is recommended to be measured as well. It is also recommended to collect nutrient samples during the surveys in quarter 1.

Sampling of trawl catches

After sorting the catch, length frequency data are collected for all fish species. Either all, or at least 50 specimens should be measured per species. In case of large catches (nb > 1 000) of any species, and if a species is caught in two or more distinct size groups, the minimum sample size should be doubled.

A few species that are hard to distinguish from one another (*e.g.* Ammodytidae, *Pomatoschistus*) may be grouped by genus or larger taxonomic unit.

Age, sex and maturity data should be collected for the eight target species: herring, sprat, mackerel, cod, haddock, whiting, Norway pout and saithe. From 1991 onwards the same sampling areas (9) are used for all species (fig. 4), and for each sampling area, eight otoliths should be collected per one or half-centimetre size class in case of herring and sprat. In addition to the collection of otoliths from the eight target species, additional sampling is advocated for by-catch species in order to increase our knowledge of the biology of less well known species.

Information exchange and storage

Each country has developed its own data input and storage programs. For data exchange a format was agreed in 1982 (ICES, 1982). Three main record types were described: for haul data, for length frequency data, and for sex/maturity/age/length key data. Some modifications have been agreed since then. A detailed description is given in the survey manual (ICES, 1996b).

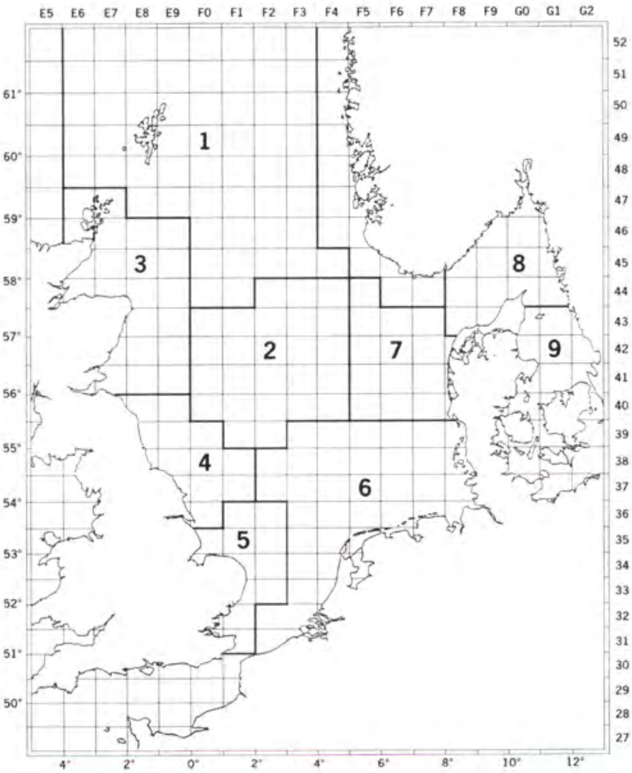


Figure 4
Otolith sampling areas as used for all species during the IBTS.

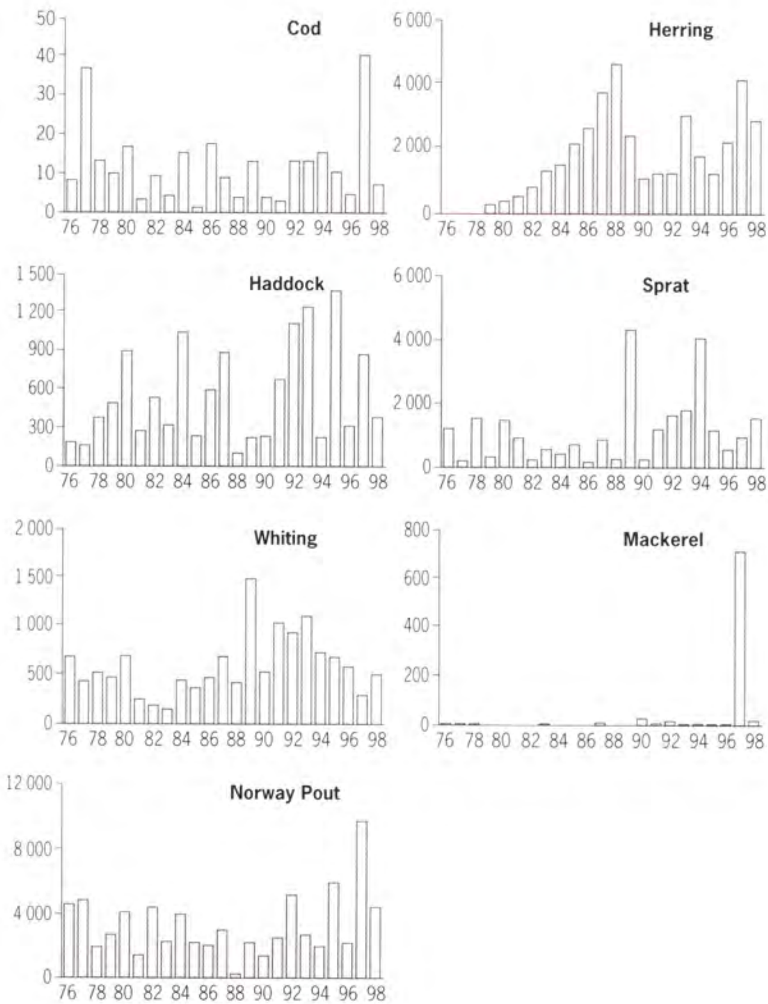
For many years, up to 1983, all data on the target species were sent to the Netherlands Institute for Fisheries Research (IJmuiden) for analysis and the calculation of abundance indices. From 1983 onwards the ICES Secretariat in Copenhagen has taken over this responsibility. After a thorough quality control the data are stored in a SIR database. Half the countries have since then also submitted the data from the years before 1983 to the database, but for the other countries these data are only available at the national institutes, and quite often not computerized. An EU funded project ('Input of historic IBTS data') aims at the input of all survey data collected since 1966. At the end of this year, the IBTS database at ICES should therefore contain a complete dataset. Recently ICES has provided all participants in the survey with a PC version of their checking and validation program (ICES, 1997c) to ensure that the data are properly checked before they are sent to ICES.
Hydrographical data are stored in a separate database: the ICES Oceanographic Databank. Fish data and hydrographical data can be coupled *via* the hydrographical station number.
The MIK data are kept in a database at the Danish Institute for Fisheries Research (Charlottenlund).

Preliminary data and standard analysis

As already mentioned, each quarterly survey is co-ordinated by an appointed member of the IBTS WG. All countries supply these co-ordinators with preliminary catch at age data based on a fixed length-split per species (for ages 0, 1 and 2+) per quarter (ICES, 1996b). During the survey in quarter 1, preliminary catch data are exchanged while the vessels are at sea (fig. 5). At the end of this survey, preliminary abundance indices are therefore available as soon as the last vessel has ended its survey.

Final data are sent to ICES in exchange format as soon as possible after the survey. In the case of the quarter 1 survey, the Herring Assessment Working Group often meets very shortly (one week) after the end of the survey. For the relevant species for this Working Group, herring and sprat, final data are usually available during the first days of the Working Group meeting. When all data are checked and stored in the

Figure 5
1-group abundance indices (average Nb/hour fishing) of the quarter 1 IBTS. 1976-1997 final indices, 1998 preliminary values.



database, a standard analysis is done by the ICES Secretariat. A description of this analysis is given in Pedersen (1989).

The calculation of abundance indices follows a standard procedure of averaging within sampled rectangles and then averaging over a 'standard area'. These standard areas are species specific and were delineated to cover the main area of distribution of the species concerned. The areas have been modified in the course of the years, partly due to changes in distribution. There is perhaps a need to re-evaluate the way in which indices are calculated in the light of advances in statistical methodology (a proposal for a study of this aspect was recently selected for funding in the call for CFP-proposals in 1998). In addition, indices are usually presented as point estimates. Some estimate of precision would be useful even if this was only the within year measurement error.

In the calculation of the survey-index for herring, the Herring Working Group introduced two important changes in 1993. Prior to that year, recruitment forecasts for 1-ringed herring were derived from the IBTS by averaging within sampled rectangles and then averaging over the 'herring standard area', a selection of rectangles with historically good herring catches, but limited to the North Sea proper. This procedure did not take the numbers of 1-ringed herring in the Kattegat and Skagerrak into account. In 1993 the number of juvenile herring in Skagerrak and Kattegat was higher than in the standard area in the North Sea. Since then the total survey area is used in the calculation of the index. In addition to this change in the area, it was also decided to weigh the rectangles differently, depending on surface area (for coastal rectangles) and percentage water shallower than 10 m, or deeper than 200 m (250 m in Skagerrak) where herring only occur in small quantities.

Recently, saithe was added to the target species of the IBTS, and it was decided to apply the same weighting in the standard analysis of the saithe data. It is not yet investigated whether for the other species similar changes could improve the performance of the indices in the tuning process.

Some attention was given to investigate the influence of different factors such as day/night effects, the influence of the use of bobbins, vessel effects, etc. (ICES, 1990). But these analyses have not been conducted for all species. A problem in these analyses is that the outcome not only depends on the species considered, but even may be age dependent. Optimization of the calculation of indices will not likely be the same for all species or age-groups within a species. And it will be difficult to optimize the survey for all species.

Access to the collected IBTS data

The IBTS data are made available for all ICES Working Groups. 'Raw' survey data, traceable to the haul level, are usually only made available to the laboratories participating in the survey. Other users can only use limited sets of aggregated data. A formal request for IBTS data must be sent to the ICES Secretariat, describing the purpose of the study. If all countries approve the study, the Secretariat can start the data retrieval.

Resulting publications and reports

For many years the Dutch Institute (RIVO) in IJmuiden collated the survey results, calculated the survey indices for the target species and published these as annual ICES, papers. More detailed information (for the years 1970-1981) was published as so-called 'database reports' in the form of internal reports.

Since 1983, the results of the analyses of the quarter 1 survey-data are routinely published as papers which are submitted to the ICES Annual Science Conference (ICES, 1997b). The results of the surveys which since 1991 have been conducted in the other quarters are published in the same series.

Vessel and scientific effort

Figure 6 shows the number of hauls per year taken in the quarter 1 survey since 1965, and the number of ICES rectangles covered. Since 1975 the total number of hauls has fluctuated between 350 and 540, and coverage has been at a high level.

During 1991-1995, when a survey was conducted in each quarter, the total number of trawl hauls was on average 1 262 per year, taken during 412 vessel-days at sea. For quarter 1, these values were 382 hauls, in 136 vessel-days. Usually seven vessels participate in the quarter 1 survey, in the third quarter there have been five vessels during the last couple of years.

On average the vessels that participate in the IBTS are staffed with 4-5 scientific persons. The number may vary from vessel to vessel, and often scientific work in addition to the IBTS work is carried out during the survey and the scientific staff is increased accordingly. Norwegian vessels usually operate in two 12-hour shifts and will have more staff on board.

Figure 6
Total number of hauls in the quarter 1 IBTS since 1966 and the number of ICES rectangles covered.

There are great differences between vessels in the degree to which the work is being completed at sea or at the laboratory: on board of some vessels, otoliths are being read, and plankton samples completely sorted, whereas in other countries this work is traditionally done on land.

Use of survey information

At present, the principal use of the IBTS indices is in the so-called "tuning" of VPAs for cod, haddock, whiting and herring in the North Sea, as well as the estimation of recruiting year classes for short-term forecasts. While this will remain one of the main purposes of the survey, there are a number of other important uses which are discussed below.

VPA tuning

Gradual changes in the IBTS such as the extension of the survey area, standardization of the survey gear, and replacement of research vessels, potentially introduce problems of calibration induced by trends in catchability. This was noted by Armstrong & Cook (1986). Their analysis was limited to the period 1968-1984 when the greatest changes in the survey occurred. Current practice by assessment working groups is to limit the tuning data in the catch at age analysis to the period from 1986 onwards (ICES, 1997a) when standardization of survey design and implementation was improved. There is little evidence that in this period there are problems of catchability trends for demersal species and the IBTS indices appear to perform as well as most other tuning data. For haddock, the IBTS receives most weight in the estimates of stock numbers for the younger ages indicating that, according the Extended Survivors Analysis (XSA), the IBTS has the greatest precision within the tuning data.

North Sea whiting assessments have always presented problems of consistency. There is a tendency for the survey data of all sources to show a different trend to that implied by the VPA (Cook, 1997). In fact there is greater consistency between the IBTS and other similar surveys than between the surveys and VPA. Given the problems with the estimation of commercial catch at age compositions, notably for discards and the industrial by-catch, it seems likely that the surveys may give a more realistic interpretation of stock trends.

In the case of herring, two indices derived from the IBTS survey are used. These are the MIK index of 0-ringers and the GOV-trawl estimates of abundance-by-age. Both indices correlate well with the VPA and are important components of the assessment. The other main tuning index used in the herring assessment is an acoustic survey carried out in June, which tends to indicate a somewhat different trend in SSB in the last decade. There is some evidence that the IBTS index of biomass is more consistent with the VPA but that the age composition within the index is less so. By contrast, the acoustic estimate age composition appears better while the biomass index seems less adequate.

IBTS data are also used for the calculation of age-structured indices for sprat. Due to the lack of sufficient data from the commercial fisheries, no assessment of the North Sea sprat stock can be made. The IBTS data do not seem to perform well for sprat: strong and weak year classes are poorly indicated and the survey does not seem to reflect the dynamics of the stock very well.

The degradation of fisheries landings data in recent years adds to the problems of using commercial CPUE data to tune assessments. Recent assessments, therefore, depend more heavily on survey abundance indices and the IBTS index is an essential element of these data.

Recruitment estimations

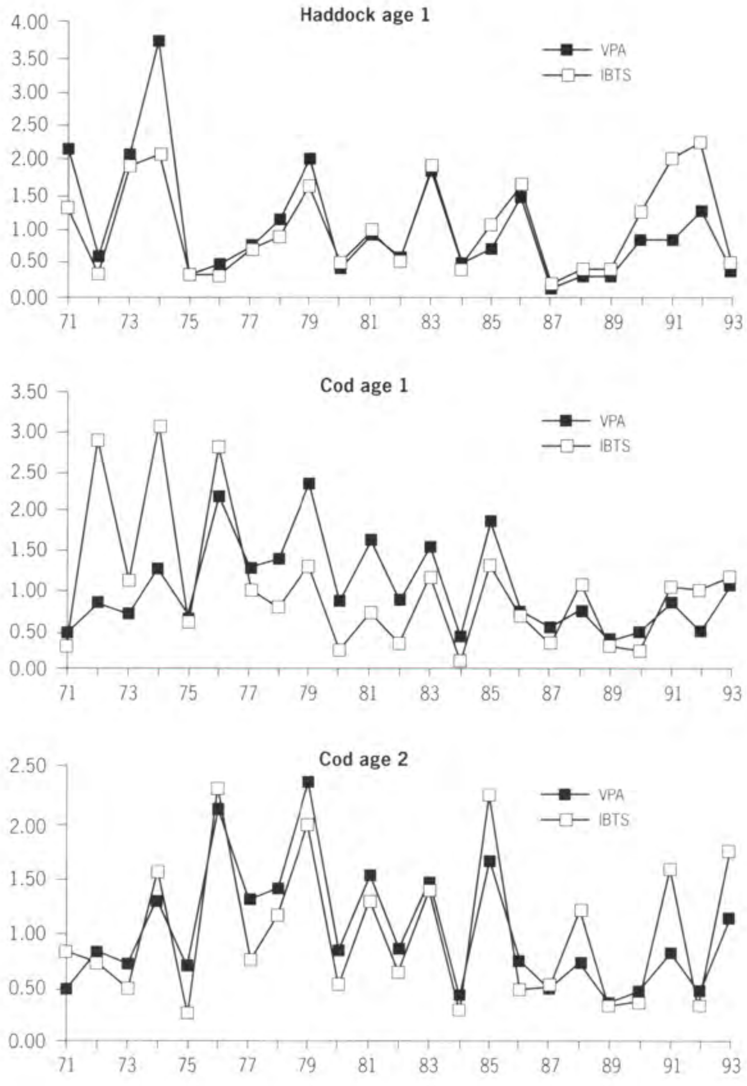
The earliest use of the IBTS was in the estimation of recruitment. It is still used in this way although the recruitment estimation is now to a large degree absorbed in the catch-at-age analysis. The conventional ICES approach to recruitment estimation is to use RCT3 (Shepherd, 1997) which combines multiple indices into a 'best estimate' using a calibration regression. For the demersal stocks where multiple survey information is available, the quarter 1 IBTS performs less well for cod when compared with the other surveys. For haddock, however, it receives high weight in the combined index (fig. 7). Recruitment estimation using RCT3 is no longer used for whiting because of the inconsistency between the surveys and VPA. As indicated above, this is more likely to be a problem with the VPA rather than the survey.

Unlike VPA tuning where only a ten-year-time series is used, the RCT3 analyses typically include data from the early 1970s and may therefore be more affected by catchability trends. Working groups generally apply a time taper which downweights the early data and therefore should reduce the problems of catchability trends. However, this is an *ad hoc* solution and it is perhaps time to re-examine this issue and determine the best use of the data.

Ecosystem effects of fishing

Survey data are becoming increasingly important to judge the 'health' of ecosystems and to answer the question in how far fisheries have influenced, and still do influence the whole ecosystem. In this respect, it is of course important to have long-term data on trends in spawning stock biomass of the commercially important species. A completely other approach recently was developed by Rice & Gislason (1996) who did not use the survey data for commercial species only, but included information on the length composition of the total catch in their analyses. In particular, comparison of slopes and intercepts of the length compositions of the fish community sampled by the survey gear, with estimates derived from MSVPA appear to provide a valuable tool to elucidate long-term trends.

Figure 7
Comparison of recruitment estimates of the assessment (VPA) and the survey (IBTS) for haddock at age 1, and cod at ages 1 and 2.



Other examples of the use of IBTS data

During the IBTS in 1981 and in 1991, and to a lesser extent in some other years, large scale stomach sampling programmes have been carried out. The purpose of these investigations was to elucidate the interspecific influences between North Sea fish species. An answer was sought for the question: 'Who eats who?'. The results of these sampling programmes on food composition, and quantities of prey, have contributed significantly to our knowledge of juvenile mortality by predation of the most important species and lead to more realistic estimates of natural mortality than the values used before.

During the survey not only information on length compositions is collected, but also otoliths are collected to determine the age composition of the catch. Data on maturity are collected simultaneously, and the resulting maturity ogives are used in the assessments to determine the part of the population that forms the spawning stock.
Up till recently, most attention was paid to the commercially important species. Fortunately enough, most countries have from the beginning of the surveys, collected information on the length composition of all species that occurred in the catch. The IBTS has therefore proved particularly valuable in providing information on non-commercial fish species. The most obvious examples of this are the studies by Sparholt (1990a, b) which provide estimates of total fish biomass and refine estimates of natural mortality.
The ICES Atlas of North Sea Fishes (Knijn *et al.*, 1993) presents an overview of the distribution of all species caught during three years (1985-1987) of quarter 1 IBTS-surveys and a combination of national surveys in quarter 3. Time series of a number of non-target species were analyzed by Heessen & Daan (1996), Heessen (1996) and Walker & Heessen (1996). The information on the quarterly distribution of fish species in the North Sea can also be used when examining different technical measures such as area closures to protect juvenile fish.
Several national and international studies are conducted during the IBTS: the vessels are out at sea, and can be used by other scientists as well. Examples of this are programmes aimed at monitoring fish diseases, and also a programme aimed at collecting information on biodiversity (an EU funded project by the Lowestoft laboratory CEFAS). This last project investigates amongst others the use of a small beam trawl at each IBTS fishing position, with the purpose of collecting benthos samples. The quarterly surveys have also been intensively used by bird watchers to map the quarterly distribution of seabirds over the area.
The hydrographical information collected during the IBTS has been used in various studies of North Sea hydrography. The IBTS data are part of a larger database, the ICES Oceanographic Data Bank. From examining studies on North Sea hydrography, it will be clear, that many of these studies are based on observations made in February during the IBTS. In biological studies, the hydrographical information has so far seldom been used. One of the few examples is an analysis of the relation between temperature and the distribution of cod in the North Sea (Heessen & Daan, 1994).

Discussion and conclusions

The present IBTS differs substantially from its original implementation. It has evolved from its earliest conception as a survey for young herring into one for demersal fish and herring of all ages and sizes. These changes are associated with a considerable extension in the area surveyed and a gradual adoption of a more or less standard survey gear. The slow transformation of the survey arose partly as a result of evolving scientific demands and partly due to inherent problems of co-ordinating work from a number of different national laboratories each with its own traditions and constraints. It is inevitable also that over time ships have gradually been replaced with new vessels. All these factors mean that the survey abundance indices are prone to variability and trends in survey efficiency or catchability.

Most analyses associated with the IBTS are devoted to the provision of abundance indices. The survey does, however, provide a substantial amount of additional information which is perhaps under-utilized. Maturity, for example, is routinely recorded yet for the main gadoids, this information is rarely examined or updated by assessment working groups. Similarly the wide coverage of the survey makes it ideal to examine annual distributions which may help in understanding why some apparently large year classes do not contribute as much to the stock as expected. Other measurements, such as temperature and salinity, are also little used. It is perhaps in these areas where more work should be done.

IBTS data are also used for biodiversity studies and studies of rare species. Proper knowledge of sampling procedures on board of different vessels and data checks should be made available, because these are likely to influence the results. Different sorting methods can introduce a bias. On board of the Dutch R/V *Tridens* for example, the catch is sorted on a conveyor belt. On other vessels the whole catch is sorted on sorting tables, basket by basket, and each single fish is handled. Small rare fish may more easily escape the attention when the catch passes on a conveyor belt, than when it is sorted on a sorting table.

The quality control of the data in the ICES IBTS Database will probably never be complete. The database almost certainly includes miss-identifications: *e.g.* in the same survey and same area one country caught only *Myoxocephalus scorpius*, whereas another country only caught a similar species *Taurulus bubalis*. Such unlikely differences become only apparent after careful analyses, but should lead to improved checks on species identifications in the future.

One of the reasons to set up the ICES IBTS Database, was to make the survey data available to more scientists. The number of requests for data is increasing.

The results of the International Bottom Trawl Survey are widely used in ICES assessments, and are becoming increasingly important in the study of ecosystem effects of fishing. To ensure future users of the IBTS results of good quality data, the fisheries institutes co-operating in the IBTS should commit themselves to proper quality checks. This not only concerns the integrity of the data that are exchanged after the survey, but also the methods used during the survey, *i.e.* fishing, sampling, ageing, etc.

At present, the IBTS seems to be under-utilized. Certain errors or inconsistencies only become apparent after extensive analyses of the data, and only then it will be possible to improve the overall quality of the survey.

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Multiple otter-trawl calibration for the sentinel surveys in the northern Gulf of St. Lawrence

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Abstract

Recent downturns in stock abundance and a new urge to collect scientific data in collaboration with fishermen have prompted the emergence of partnerships between science and the fishing industry. Since the fall of 1994, a series of collaborative projects has been initiated with fishermen with the aim to better monitor abundance of commercial species - like cod - which are under moratorium along the eastern shores of Canada. These are known as "Sentinel Fisheries".

In the northern Gulf of St. Lawrence (NAFO Divisions 3Pn, 4RS), sentinel fisheries are conducted by fishermen using both fixed and mobile gear. This paper describes efforts to involve nine commercial otter-trawlers to perform two seasonal groundfish surveys following a stratified-random sampling design. These nine boats have different characteristics and may bias the single index of abundance derived through the use of a standard trawl. These are somewhat different than the traditional groundfish surveys conducted aboard a single research boat as they may add significantly more variability to the index of abundance because of their different levels in catching performance.

This paper introduces the various types of influences that may occur with the use of multiple boats and ways to reduce their impact on the abundance index. This is followed by two field experiments that are aimed to reduce this variability. To begin these surveys, a first step to minimize inter-boat variability in wingspread was the use of a single type of fishing gear. Despite this, results of the first field experiment monitored with Scanmar technology produced a 25% variability in the wingspread among the nine boats. The wingspread is important as it is the variable by which the abundance index is derived. The next step in standardizing the catching performance of fishing gears used in these surveys was to apply a restrictor cable to physically limit the wingspread of the trawls used by all nine boats. The proper adjustment of this cable reduced the inter-boat variability to six per cent. Another advantage that comes with the use of this technique, is that the opening of the trawl is not influenced by the towing depth, a common bias that is well documented in groundfish surveys. Finally, results of the first operational survey to use the restrictor cable (the seventh in the time series) are presented along with considerations on ways to introduce this technique to the analysis without compromising the time series.

These efforts to standardize the trawl geometry for nine different commercial boats that conduct seasonal stratified-random surveys have greatly reduced inter-boat variability and thus allow for the establishment of two improved new time series (July and October) of index of abundance for cod in the northern Gulf of St. Lawrence.

Introduction

Results of groundfish surveys are inherently very variable. This is mainly due to the high level of aggregation of the fish encountered and the variability caused by the topography and physical environment of the sea. An additional source of variation can be found when multiple boats are conducting a single survey. This may be the case for sentinel fisheries.

Much effort has been devoted to measure and control this variability over the years (Gavaris & Smith, 1987; Koeller, 1991; Korotkov, 1984; Main & Sangster, 1981; Strong, 1992) yet few addressed the added variability brought by the use of multiple vessels (Engås & Ona, 1991, 1993). There are many ways to reduce the variability of abundance estimates (sampling intensity and allocation, consistent sampling protocol in relation to the environment - towing speed, directions to currents, parallel tows, fewer strata, multiplicative modelling to take into account missing strata and/or day night effects, use of submarine monitoring apparatus such as Scanmar). Any variation in wingspread may have important repercussions on the estimation of a minimal trawlable biomass by the swept area method. We shall examine one of the few tools available to reduce potential variability that may occurr in the use of multiple vessels, the restrictive technique (Engås & Ona, 1991, 1993). This approach was used in the context of sentinel surveys that are conducted by nine otter-trawlers in the northern Gulf of St. Lawrence since 1994.

Material and methods

All nine boats participating in the northern Gulf of St. Lawrence sentinel fisheries were equipped with a standard trawl, a Rockhopper 300 (see the table, p. 39). This gear was selected after discussions with the fishermen involved in selecting a gear they were familiar with and rugged enough to trawl on rough bottom. This trawl is adapted to these boats which range from 45 to 65 feet in length and have engines ranging between 325 and 503 horsepower. A 40 mm liner has been added to the codends of these trawls to catch small fish for recruitment estimation (Fréchet *et al.*, 1995). The fishing tows are of half an hour duration at a towing speed of two and a half knots. The fishermen have been trained to collect biological data throughout the surveys. There has been only two boats that have changed after seven seasonal surveys. This allows for adequate and efficient sampling by the fishermen involved.

Description of the nine vessels involved in the sentinel fisheries for the 3Pn, 4RS cod stock.

Vessel	*Annie Annick*	*Sextan*	*Forillon*	*Rémi Martin*	*Mazie & Murray II* (1)	*Miss Way*	*Northern Tip*	*885*	*Lady Christanna*
Length (ft)	60'	55'	65'	45'	58'	55'	55'	55'	45'
Horsepower	503	402	335	325	365	365	365	450	400
Reduction gear	5-1	5-1	3-1	4.5-1	4.5-1	4.5-1	4.5-1	5-1	4-1
Propeller type	Variable	Variable		52"	50"	54"	54"	58"	46"
Pitch (in)				36"	46"	44"	36"	50"	40"
Cort nozzle	No	Yes	No		No	No			
Gear									
Trawl type	300 Balloon	300 Balloon	300 Balloon	300 Balloon	300 Balloon	300 Balloon	300 Balloon	300 Balloon	300 Balloon
Footgear disk diam. (in)	12"	12"	12"		Rockhopper	Rockhopper	Rockhopper	Rockhopper	Rockhopper
Footgear chain size (in)	3/8"	3/8"	3/8"						
Number of floats	51	43	51	48	51	51	51	51	51
Float diameter (in)	8"	8"	8"	8"	8"	8"	8"	8"	8"
Bridles length (ft)	120'	120'	120'	120'	120'	120'	120'	120'	120'
Extension (ft)	20'	80'	16'	60'	60'	60'	60'	60'	60'
Main wire length (ftms)	400	600	375	325	400	325	425	500	525
Main wire diameter (in)	5/8"	5/8"	5/8"	5/8"	9/16"	1/2"	5/8"	9/16"	1/2"
Doors type	Morgère 520 kg	Morgère 520 kg		Bison # 8.5	Cosalt	Bison # 9	Cosalt	Cosalt	Cosalt
Surface (sq ft)	40	40	36		42		36.6	41.8	36.6

(1) = replaced by *Salt Water Foam* in 1996.

Two separate contracts were awarded to Nordsea, the Canadian dealer of Scanmar technology, to conduct sea trials on these nine boats. The first step (done in 1995) aimed at verifying the inter-vessel variability of unconstrained wingspread (Fréchet, 1996). The second step was conducted in 1996 to adjust and install a restrictor cable (Engås & Ona, 1991, 1993) on each boat to minimize the variation measured the first year (Fréchet, 1997). Sea trials were done at different depths (from 137 m to 365 m, 50 - 200 fathoms) to evaluate its impact on wing-spread. The restrictive technique has also the advantage of allowing some turnover in any of the nine boats involved. Any new participants should ideally be submitted to the two phase calibration (unconstrained/ constrained) or use an empirical relation based on this relation. See Fréchet (1997) for details on the building materials and the installation procedures of the restrictor cable.

The restrictor cable was used for the first time by all participants during the July 1997 survey (the seventh of the time series). Compliance and comments on the field operations are also presented and discussed. Finally, the use of the restrictor cable has implications for the time series when results are expressed as catch rates (kg per 30 min tow) but not when expressed as minimum trawlable biomass.

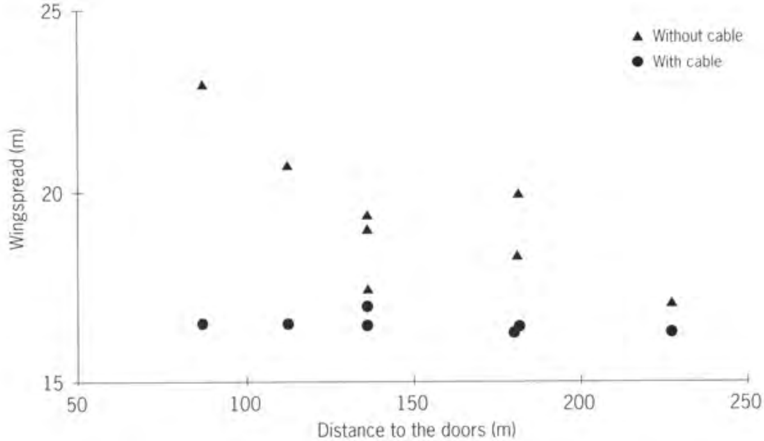
Results

Before attempting to modify the configuration of the trawls involved in sentinel fisheries, it was important to measure the degree of variability of unconstrained wingspreads. This first step yielded a 25% variability in wingspread among the nine boats involved (from 17 m to 22 m) and the wingspread showed a tendency to increase with depth (Fréchet, 1996). This means that steps should be undertaken to minimize this variability.

A positive correlation existed between wingspread and doorspread ($r = 0.63$) and a negative correlation existed between wingspread and vertical opening ($r = -0.36$) (fig. 2). This means that the wingspread could be considered as a proxy for the trawl geometry as a whole. A principal component analysis based on wingspread and doorspread as well as vertical opening could actually predict the geometry of the trawl for each individual boat (Fréchet, 1996).

The second step in the calibration was to properly adjust and install a restrictor cable between the main warps leading to the doors. The target wingspread was established at 16.5 m (± 0.5 m). This is slightly less than the minimum value observed in the first sea trials (17 m). This was done in order to maximize the efficiency of the restrictor cable for all boats. After the sea trials, it was found that the position of the restrictor cable relative to the doors was proportional to the spread on the unconstrained wings (fig. 1).

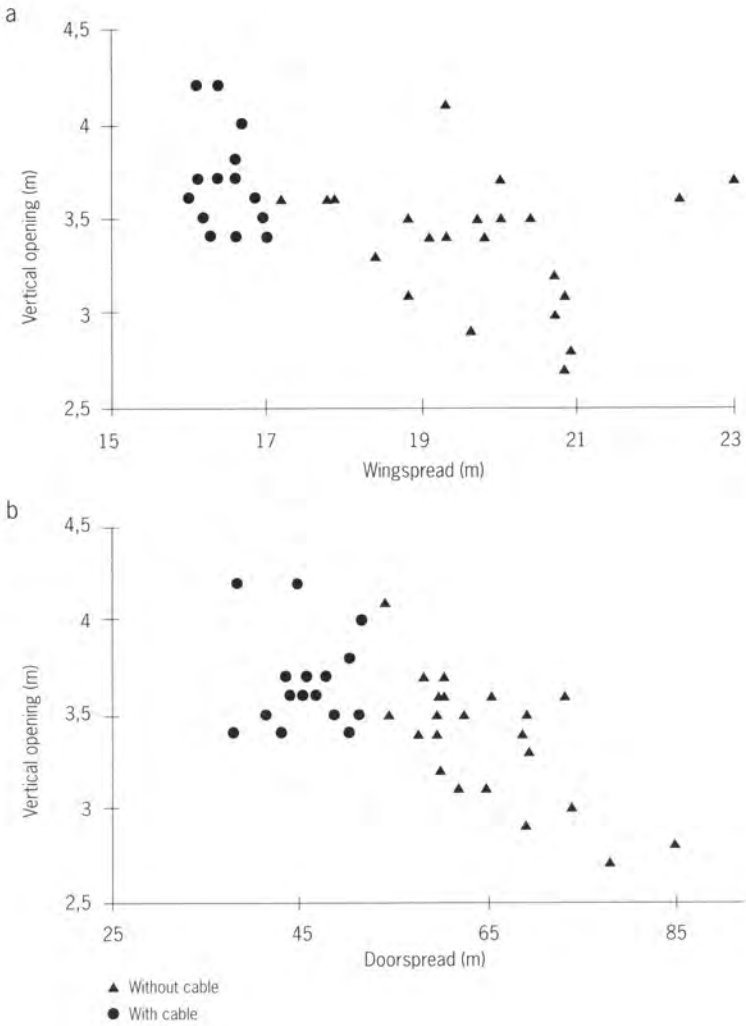
Figure 1
Relationship between unconstrained wingspreads and the position of the restrictor cable in order to adjust all boats to a target wingspread of 16.5 m (± 0.5 m).



This empirical relationship allows for some degree of turnover in participants. This is to be expected. Two boats have already changed since the inception of sentinel projects in the fall of 1994. Their replacement should ideally be recalibrated with a complete set of sea calibrations in order to properly adjust the restrictor cable to fit with the vessel's specifications. If this is not feasable, the restrictor cable could be installed at a position predicted by the relationship shown in figure 1.

The trawl operates as a flexible three dimension structure. Any increase in wingspread caused by an increase in doorspread will reduce the vertical opening (fig. 2). This effect is cancelled when the restrictor cable is used. The larger wingspreads generally occur at greater depths (fig. 3). This is due to the large amount of main warp being used at a scope ratio (fishing depth, warp length) of 1:3 and 1:2 in depths over 200 fathoms. The use of the restrictor cable will reduce considerably the variability in the trawl geometry (fig. 2).

Figure 2
Impact of the restrictor cable on the vertical opening (a) and on the doorspread (b).



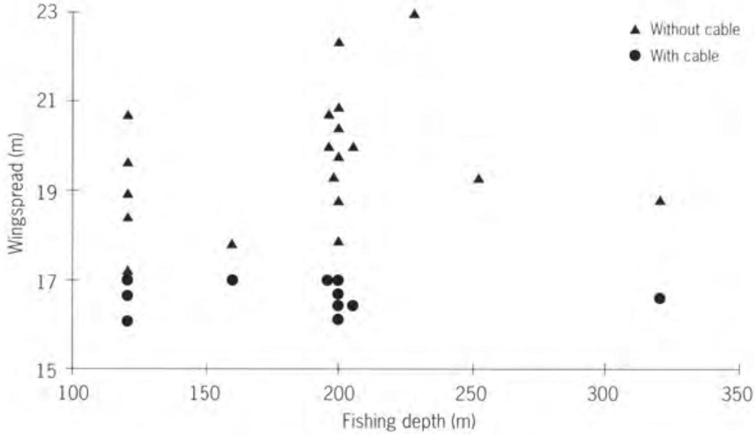


Figure 3
Effect of fishing depth on wingspread.

In the unconstrained situation, the index of abundance, expressed as minimal trawlable biomass ('000 t) is given as:

$$UB = \sum_{s=1}^{S} \left(\frac{S_a}{U_{us} T_s T_d} \right) \left(\frac{\sum_{t=1}^{T} U_{ct}}{n} \right)$$

In the constrained situation, the index of abundance, expressed as minimal trawlable biomass ('000 t) is given as:

$$CB = \sum_{s=1}^{S} \left(\frac{S_a}{C_{us} T_s T_d} \right) \left(\frac{\sum_{t=1}^{T} C_{ct}}{n} \right)$$

In the unconstrained situation, the index of abundance, expressed as average catch per tow (kg/30 min tow) is given as:

$$\overline{Cu} = S_a \frac{\left(\frac{\sum_{t=1}^{T} U_{ct}}{n} \right)}{S_a}$$

In the constrained situation, the index of abundance, expressed as average catch per tow (kg/30 min tow) is given as:

$$\overline{Cc} = S_a \frac{\left(\frac{\sum_{t=1}^{T} C_{ct}}{n} \right)}{S_a}$$

where:

UB	= Unconstrained minimal trawlable biomass
CB	= Constrained minimal trawlable biomass
$\overline{Cu}$	= Unconstrained average catch per tow
$\overline{Cc}$	= Constrained average catch per tow
Sa	= Strata area
U_{ct}	= Unconstrained catch in tow $_t$
C_{ct}	= Constrained catch in tow $_t$
U_{ws}	= Unconstrained wingspread
C_{ws}	= Constrained wingspread
T_s	= Towing speed
T_d	= Towing distance
n	= Number of tows in strata $_t$
s	= Number of strata in survey

The seventh survey (July 1997) conducted by these nine boats used the restrictive method as a standard for the first time. Even though fishermen had been involved with the calibration process all along, some field problems were expected by both skippers and scientists. It was believed that the cable would increase the probability of crossing the doors leading to an unsuccessful tow. Fishermen were also hesitant to clamp the cable past the main blocks. Although the initial cables were made of 13 mm (1/2 inch) fibercore steel, a non elastic nylon cable was accepted for security reasons afterwards. One end of the restrictor cable was set fast to the main warp and the opposite was allowed to slide on the other warp to allow for bad bottoms, currents and manoeuvres of the boats. Compliance to the use of this new technology was over 90% during the seventh survey.

Discussion

Initial trials at sea demonstrated that the trawl used by all boats involved in sentinel fisheries did not behave as a single unit. A 25% degree of variability was estimated among these nine boats. This may not result in 25% variation in catch as the wingspread is a proxy for the trawl geometry as a whole. An increase in wingspread is accompanied by a reduction of the clearance (vertical opening) of the trawl relative to the bottom. Given that different species behave differently to an upcoming trawl (Main & Sangster, 1981), a simple weighting of the catch based on the wingspread coefficients is not appropriate. The sampling gear (the trawl) had to be calibrated and standardized.

Fish species, such as cod, have shown a strong trend to shift their distribution towards larger depths in Canadian waters recently (D'Amours *et al.*, 1994; Rollet *et al.*, 1994). Any change in trawl geometry linked with fishing depth could cause important biases in the abundance index as the same body of fish would not be exposed to the same fishing area (Koeller, 1991; Strong, 1992). The use of the restrictive techniques cancels this effect. Few groundfish surveys have yet adopted such a fishing strategy.

The resulting catch is thus expected to be reduced in proportion to the level of constraint for each boat (difference between constrained and unconstrained wingspreads). Although the mean catch per tow is reduced, the main objective of this procedure was to have a uniform gear configuration for all nine boats. The inter-vessel variability has thus been reduced from 25% to 6% without bias due to depth. The calculation of a minimum trawlable biomass in the unconstrained situation was set at 19 m and was reduced to 16.5 m when the restrictor cable was used.

Special caution must be taken to adequately adjust the abundance time series with the use of a restrictor cable. This does not apply for the calculation of the minimum trawlable biomass as the trawlable unit is proportionnaly reduced in the constrained situation. This expansion factor used to extrapolate the mean catch per tow to the total strata area takes this into consideration. The current practice is to express the abundance index as a catch rate unit (kg per 30 min tow) rather than as an abundance index (given in thousand tons). This means that catch rate indicies from past unconstrained surveys are not comparable to recent surveys that use the restrictor cable. Catch rates of the fleet must be adjusted to render the time series continuous. This can be done by applying the rate of reduction attributable to the restrictor cable to past catches for each tow, on a boat-by-boat basis, before calculating an overall catch rate.

The use of the restrictor cable in the most recent survey has reduced the coefficient of variation (CV) around the estimate of the index of abundance (mean catch per tow) for cod in the area from an average of 44% to 55% in the past six seasonal surveys (July and September respectively) to only 25 per cent. Many other causes may have influenced this CV, but it is likely that the restrictor cable is a prime element enhancing the accuracy of the survey.

Conclusion

Recent downturns in the groundfish stocks of Atlantic Canada has prompted more collaboration between science and industry. The advent of sentinel fisheries has been an occasion to blend a rigourous scientific protocol to the traditionnal knowledge and expertise of fishermen to produce reliable results. The mobile gear survey in the northern Gulf of St. Lawrence has greatly improved with the use of the restrictor wire, it allows a very quick (7 to 10 days) and unbiased estimate of the groundfish resource in the area. The trawls from all nine boats using the restrictor cable now behave as a single sampling unit.

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Acknowledgments

I wish to thank the sponsors and co-ordinators of the sentinel surveys, the fishermen from the nine vessels involved as well as for the personnel from Nordsea for their great collaboration in the context of this study.

Demersal trawl surveys in Italian seas: a short review

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Abstract

Within the framework of Italian Law 41/1982 regarding multi-annual plans to improve fishery management and fish farming, a part of the funding was allocated to the assessment of fishery resources, mainly by direct methods. Thus, in 1984-1985 bottom trawl surveys were initiated in all Italian seas within GFCM statistical sub-areas 37.1.3, 2.1, 2.2. Fifteen Operative Units were divided into three separate groups until 1993, and stratified random sampling and transect system design were used. From 1993, the Operative Units were reduced to eleven, all belonging to the Gruppo Nazionale Risorse Demersali (GRUND). The same standardized protocol and stratified random sampling scheme were used in all seas during two surveys per year (1994-1995): one in spring and the other in autumn. Over a total surface area of 209,372 km^2, 482 hauls per survey were carried out. The following ten target species were considered: *Mullus barbatus* (L.), *Merluccius merluccius* (L.), *Phycis blennoides* (Brunn.), *Micromesistius poutassou* (Risso), *Nephrops norvegicus* (L.), *Aristaeomorpha foliacea* (Risso), *Aristeus antennatus* (Risso), *Parapenaeus longirostris* (Lucas), *Octopus vulgaris* (Lam.), and *Eledone cirrhosa* (L.). At present, the GRUND-2 surveys (1996-1999) are combined with the international bottom trawl survey MEDITS (a single cruise in spring). All hauls of the previous two cruises per year are now concentrated in an autumn cruise, with 1,085 hauls over a surface area of 285,032 square kilometres. Within this programme, selectivity (codend mesh) and intercalibration (boats and nets) investigations are planned or in progress.

Introduction

Experimental sampling using a trawl and indirect estimates based on the study of landings are the two methods best suited to the assessment of demersal fishery resources. The ideal solution would be to use both direct and indirect methods at the same time (Levi & Andreoli, 1979), but this is impossible in terms of current financing, means and availability of operators, and the difficulty of obtaining commercial data in some areas.

Italian Law 41/1982 provides for multi-annual plans to improve fishery management and aquaculture. A review of the results obtained is available in the Proceedings of the Conference "Le ricerche sulla pesca e sull'acquacoltura nell'ambito della L. 41/82" (Biol. Mar. Medit., 1998, 5 (3), part I: 1-874, part II: 875-1702, and part III: 1703-2500; a fourth volume is in press). As part of these plans, a share of the financial resources from the Ministero Marina Mercantile (MMM), Direzione Generale della Pesca Marittima [the name of the Ministry was changed first to Ministero Risorse Agricole, Alimentari e Forestali (MRAAF) and later to its present name of the Ministero per le Politiche Agricole (MiPA)] is devoted to scientific and technical research. In 1984-1985, these funds made it possible to begin a comprehensive investigation into biological resource evaluation in seas within FAO-GFCM statistical sub-areas 1.3, 2.1, and 2.2 of area 37 off the Italian coast (fig. 1). The present paper deals with bottom trawl surveys carried out or planned from 1985 to 1999 in Italian seas for evaluation of demersal resources within the Italian national programme (1984-1986, 1987-1989, 1991-1993, and 1994-1996 triennial plans). The MEDITS cruises (Mediterranean International Trawl Survey; Bertrand *et al.*, 2000), financed half by the European Union and half by national bodies (MiPA), are not considered. These surveys began in 1994 and have been co-ordinated with national cruises since 1996, with sampling at the same stations.
Before 1984, some investigations into the otter trawl fishery in Italy were financed by the MMM (Froglia, 1984) and the National Research Council (CNR - Programma Finalizzato Oceanografia) (Relini, 1978; Relini Orsi & Relini, 1982; Relini Orsi *et al.*, 1979, 1982), but they were limited in time and space, except for the central and northern Adriatic (Jukic & Piccinetti, 1981; Piccinetti & Jukic, 1984). Other interesting data were collected in Sicily (Arena & Li Greci, 1973; Bombace & Sarà, 1972; Sarà, 1969), Sardinia (Cau & Mura, 1978), the Adriatic Sea (Froglia & Gramitto, 1982; Marano *et al.*, 1977), Tuscany (Matta, 1958), the Ligurian Sea (Orsi Relini *et al.*, 1985; Relini, 1985a; Relini *et al.*, 1985a, b; Relini Orsi & Fanciulli, 1980; Relini Orsi & Relini, 1973; Zunini Sertorio, 1975). However, all these studies were carried out at different time periods and with different methods. Important data on demersal resources and related fleets were collected during PESTAT, a quality check programme designed and executed by the Istituto di Ricerche sulla Pesca Marittima (CNR) of Ancona, with technical assistance provided by the FAO. The purpose was to assess the quality of the Italian fisheries' statistical system and improve the accuracy of the statistics produced. Two types of surveys were carried out: a Quality Check Survey on fleet statistics, aimed at assessing the quality of the existing registries of fishing vessels and providing reliable estimates of the number of fishing vessels, their operational characteristics, their geographic distribution, etc. (Bazigos *et al.*, 1984); and a Quality Check Catch and Effort Sample Survey on production statistics, aimed at providing up-to-date reliable estimates of catch and effort statistics (Cingolani *et al.*, 1986).

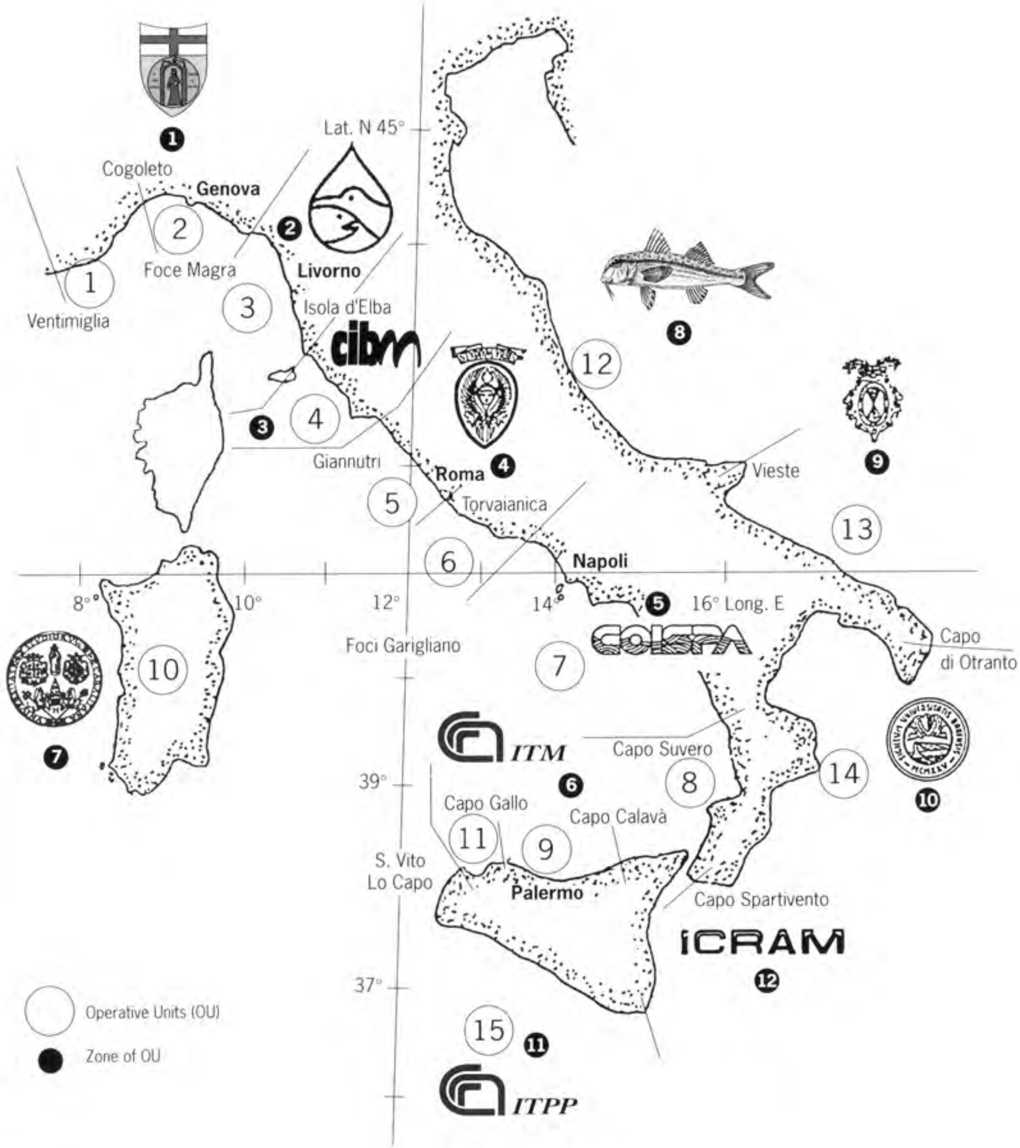


Figure 1
Zones in which 15 Operative Units worked from 1985 to 1988, and zones of 12 Operative Units involved in mapping Italian demersal resources.
The first 11 groups belong to GRUND (see table 2).

First series of surveys (1985-1988)

Demersal resource investigations were carried out in Italian waters for the first time during the period 1985-1988. At that time, 15 Operative Units (OU) (fig. 1, table 1) worked on bottom trawl surveys in all Italian seas (except the Ionian part off Sicily), employing more than 120 researchers and technicians and 17 motor-trawlers (the Sardinia OU

operated with three boats at the same time). They were divided into three groups (MMM-CNR, 1988; Levi, 1988; Piccinetti, 1988):
- the Liguro-Tyrrhenian group co-ordinated by G. Relini (No. 1-11);
- the Adriatic-Ionian group co-ordinated by C. Piccinetti (No. 12-14);
- the Sicilian Channel OU chaired by D. Levi (No. 15).
The sampling design was discussed during meetings at which European and US experts participated (Fogarty, 1985). The literature was reviewed and a decision finally taken.

Table 1 - Names of Operative Units and their Heads from 1985 to 1988.

No.	Operative Units (OU)	Head
1	CBM, Genova	Dr N. Repetto
2	Laboratorio di Biologia Marina ed Ecologia Animale - Istituto di Anatomia Comparata - Istituto di Zoologia. Università di Genova	Pr G. Relini
3	ISTIP, Livorno	Dr R. Auteri
4	Centro Interuniversitario di Biologia Marina di Livorno	Dr S. De Ranieri
5	COIPA, Roma	Dr R. Minervini
6	Dipartimento di Biologia Animale e dell'Uomo Università di Roma	Dr G.D. Ardizzone
7	Tecnoittica Roma/Bari	Dr C. Costa & Dr[ssa] M.T. Spedicato
8	Dipartimento di Biologia Animale ed Ecologia Marina Università di Messina	Pr F. Faranda & Pr G. Cavallaro.
9	Istituto Talassografico (CNR) di Messina	Dr A. Cavaliere
10	Istituto di Zoologia. Università di Cagliari	Pr A. Cau
11	Istituto di Zoologia. Università di Palermo	Pr S. Riggio
12	Laboratorio di Biologia Marina e Pesca, Fano	Pr C. Piccinetti
13	Laboratorio Provinciale di Biologia Marina, Bari	Pr G. Marano
14	Istituto Sperimentale Talassografico - CNR, Taranto Istituto di Zoologia e Anatomia Comparata Università di Bari	Pr A. Tursi
15	Istituto di Tecnologia della Pesca e del Pescato Mazara del Vallo	Dr D. Levi

In an attempt to estimate demersal resources, a direct sampling method (random stratified design for trawl surveys) was chosen during this first period (table 2) because:
- the list of settled species was not yet known for many areas;
- the official statistical data were not reliable, which is still the case;
- the sampling of the catch and of the fishing fleets was difficult as well as onerous. Nevertheless, during the last year (1987-1988), Group One made an attempt to assess the landings.

Table 2 - Italian trawl survey schemes during the period 1985-1999.

1985-1988				
Group	***OU***	***Sampling scheme***	***Calendar***	***Species studied***
1	1-11	Random sampling with bathymetric strata: 0-50 50-100 100-200 200-450 450-700	Two surveys per year: late summer and spring, repeated three times	Extensive study of ten species. Other species chosen by each OU
2	12-13	Transect design		Most of the target species were the same as those chosen by Group One
	14	*Id. OU 1 to 11*		
3	15	Random sampling with bathymetric strata: 0-50 50-200 200-400 400-600 600-800	Four seasonal surveys, during two years One year without survey	
1990-1993				
Group	***OU***	***Sampling scheme***	***Calendar***	***Species studied***
1	1-7	Transect design Landings in four strata: 0-50 50-200 200-450 450-700	Three surveys per year: spring, summer, autumn	Ten target species
2	8-10			
3	11	Random sampling with bathymetric strata	Four seasonal surveys per year, during two years One year without survey	
1994-1996				
Group	***OU***	***Sampling scheme***	***Calendar***	***Species studied***
GRUND-1	1-11	Transect design Random sampling with bathymetric strata: 0-50 50-100 100-200 200-450 450-700	Two surveys per year: spring and autumn	Ten target species
1996-1999				
Group	***OU***	***Sampling scheme***	***Calendar***	***Species studied***
GRUND-2	1-11	Random sampling with bathymetric strata: 0 (10)-50 50-100 100-200 200-500 500-800	One survey per year: autumn co-ordinated with spring MEDITS cruise	

Each zone was subdivided into strata according to bathymetric lines, because at this stage and almost everywhere other data such as those concerning biocoenosis, the kind of bottoms, and the density of the fishing populations were not available. The programme for sub-area 1.3 was described during a FAO-GFCM meeting in Mazara (Relini, 1985b). As indicated at this meeting, the knowledge of all the above-mentioned data would allow researchers to develop a better sampling design, as suggested by the literature on the subject at that time (Alverson, 1971; Doubleday, 1978, 1981; Grosslein & Laurec, 1982; Saville, 1977). More recently, Pennington (1986) and Pennington & Voelstad (1989, 1991) considered the optimal-size sampling unit for precise population estimates and minimisation of the total cost of the survey. In the Atlantic, trawl surveys have been programmed for one or two species at the most, on the basis of 20 to 30 years of data-gathering. Under these conditions, it is clear that sampling is almost perfect and that the results enable modifications to be estimated in time and expectations to be determined for the coming years. In the Italian case, researchers started from completely different premises, intending to have an idea about the consistency of stocks of the most commercially important species at 0 to 700 m in depth. However, they also wished to obtain preliminary information about the biocoenosis of the bottom. For this reason, an important part of the catch discard was kept and placed at the disposal of experts of the Italian Society of Marine Biology. Thus, there was a double advantage: a contribution to improving knowledge of the distribution of the single species and of the taxocoenosis, and a definition of the biocoenosis upon which trawling is carried out.

In the Adriatic Sea (Piccinetti, 1988), OUs No. 12 and 13 used transect design, but because of the peculiarity of the bottom (most of the stations did not exceed a 50 m depth) it was possible to analyse the data by applying post-stratification (Fogarty, 1985).

For Group One and OU No. 14 (Tursi *et al.*, 1988), five main strata were defined according to bathymetric lines (table 2). Group Three used different strata (table 2) (Levi, 1988).

Each stratum was subdivided into squares and rectangles (areas) about three miles long, corresponding to one hour of trawling. Randomisation was performed in both annual cruises. At each depth, the hauls lasted one hour (from the moment the net touched the bottom to the time the ropes were drawn up). Hauls were performed from one hour after sunrise to one hour before sunset.

The same net was used at all depths. In particular, the codend was the type generally used on bathyal (more than 200 m depth) bottoms by each local fishery.

The number of hauls performed in each stratum was proportional to the extension of the surface area of the stratum. Non-trawlable areas were excluded from hauls, but taken into account in estimating stratum surface area. Unexplored areas were regarded as trawlable. In these latter zones, a haul was considered valid if 2/3 of the time (one hour) had passed or 2/3 of the distance (three miles) had been covered.

In general, a positive relationship occurs between the mean and variance for species obtained in trawl surveys (Sissenwine *et al.*, 1983, in Fogarty, 1985), so that it is useful to consider allocating more samples in strata where abundance is high rather than employing a strict proportional allocation scheme (Fogarty, 1985). However, in our case it was impossible to apply this possibility because of a lack of basic information and because our surveys dealt with many species, each with different zones of higher density.

Two periods a year (late summer: from August 15th to September 15th; and spring: from March 15th to April 15th) were chosen for Group One and Group Two. Group Three carried out four seasonal cruises for two years and spent one year processing the data.

It was decided that Group One would carry out an exhaustive study into the biological aspects of the ten target species recorded in table 3.

Table 3 - Target species chosen by different groups during the period 1985-1999.

		Adriatic Sea 85-93 (2)			Tyrrhenian Sea (1)		Sicilian Channel		GRUND-1	GRUND-2	ICRAM
		N-C	S. 85-87	S. 90-93	85-88	90-93	85-87	90-93	94-96	96-99	88-90
Hake	*Merluccius merluccius*	•	•	•	•	•	•	•	•	•	•
Red mullet	*Mullus barbatus*	•	•	•	•	•	•	•	•	•	•
Striped red mullet	*Mullus surmuletus*	•					•	•		•	•
Common pandora	*Pagellus erythrinus*	•			•		•	•		•	•
Greater forkbeard	*Phycis blennoides*			•		•			•	•	
Blue whiting	*Micromesistius poutassou*			•		•			•	•	
Poor cod	*Trisopterus min. capel.*	•		•							
Rock fish	*Helicolenus dactylopterus*			•			•	•		•	
Fourspotted megrim	*Lepidorhombus boscii*		•	•						•	
Smallspotted catshark	*Scyliorhinus canicula*	•					•				
Norway lobster	*Nephrops norvegicus*	•		•	•	•	•	•	•	•	•
Giant red shrimp	*Aristaeomorpha foliacea*			•	•	•	•	•	•	•	•
Blue and red shrimp	*Aristeus antennatus*				•	•	•	•	•	•	•
Deep-water pink shrimp	*Parapenaeus longirostris*			•		•	•	•	•	•	•
Spottail mantis shrimp	*Squilla mantis*	•		•						•	
Common cuttlefish	*Sepia officinalis*	•	•	•	•						•
Common octopus	*Octopus vulgaris*			•	•	•			•	•	•
Musky octopus	*Eledone moschata*	•	•	•	•					•	
Horned octopus	*Eledone cirrhosa*	•	•	•	•	•			•	•	
European squid	*Loligo vulgaris*	•		•			•	•		•	
Broadtail squid	*Illex coindetii*						•	•		•	•

(1) The ten target species of Group One were also used by the Ionian Sea Operative Units.
(2) In the North (N) and Central (C) Adriatic, the following target species were also used:

Piked dogfish	*Squalus acantias*
Thornback ray	*Raja clavata*
Mediterranean horse mackerel	*Trachurus mediterraneus*
Black goby	*Gobius niger jozo*
Angler	*Lophius piscatorius*
Black-bellied angler	*Lophius budegassa*

Ten species were investigated in common, but each OU had the opportunity to choose other (locally important) species for thorough study. Most of the target species were also the same for Groups Two and Three (table 3).

All the fished material was divided on board into the following portions: 1) commercial product, 2) discard, 3) dirty, 4) waste. All data were reduced to fit a one-hour haul.

"Discard" is the portion made up of all those species of fish, crustaceans and cephalopods which have no market value but could find a use in the future (*e.g.* for zooculture); "dirty" corresponds to invertebrates which are difficult to use and vegetal detritus; and "waste" is material of anthropic origin.

All fractions of the catch were weighed. When observations and measurements could not be completed on board, all (or some of) the samples of the target species were frozen and sent to laboratories where all individuals were measured, weighed, sexed and their gonads and otoliths taken for further studies.

The documentation supplied by Group One at the end of the study (based on 3 summer and 3 spring surveys) is listed in table 4. The other two Groups were also able to provide the same information, processing and standardization of the data.

During the last year (1987-1988) the group concerned with sub-area 37.1.3 collected monthly data on fish landed by trawlers in some test harbours, with particular reference to target species.

Table 4 - Main data supplied to the Fishery General Directorate at the end of each three-year plan.

No.	Content
1	A map showing the position of the hauls during the surveys, a map of non-trawlable areas, bathymetric strata when appropriate.
2	Main characteristics of the net and fishing boat.
3	Surface areas per stratum and number of hauls per stratum.
4	A list of species of Fishes, Cephalopods and Crustaceans (Decapods and Stomatopods) found during the surveys.
5	Commercial catches divided into Fishes, Cephalopods and Crustaceans (kg/h and percentage of the three categories in relation to the total commercial catch). Data were reported for each survey, haul and stratum.
6	Species number of Fishes, Cephalopods and Crustaceans, with the percentage of commercial species.
7	Catch per hour in weight (standardized data because of different nets and boats) of the commercial part, discard, dirty, waste.
8	Catch (kg/h) of the ten target species per stratum and survey (mean and standard deviation).
9	Length distribution of target species per stratum and survey.
10	Biological parameters of target species available in the area: a) length/frequency distributions for each survey and stratum; b) sex-ratio; c) growth parameters; d) length/weight relationship; e) maturity; f) mortality.
11	Nursery area of target species.
12	Other data if important for the local OU.

Sicilian-Ionian Sea (1988-1990)

In the southern part of the Ionian Sea, from Capo Peloro (ME) to Portopalo di Capo Passero (SR), six trawl surveys were conducted by ICRAM (Andaloro *et al.*, 1993; Campagnuolo & Andaloro, 1998) during the three years 1988-1990. Because of the type of bottom, the main part of this area is difficult for, or forbidden to, trawl-fishing. For this reason, the area was investigated for a short period and abandoned until the 1996 GRUND survey.

Second series of surveys (1990-1993)

The plan scheduled to be carried out during the period 1989-1991 was delayed for two years. Research began on 1st July 1990 and ended in October 1993. The number of OUs in the Tyrrhenian group was reduced from 11 to 7 (the first seven of table 5), whereas the other two Groups remained the same.
During this second period, the sampling design was changed in most of the areas from the random stratified to the transect scheme in combination with a landing survey at several ports. Only the Sicilian Channel Group maintained the random stratified sample design.

Table 5 - Demersal Resources National Group (GRUND, 1994-1996), co-ordinator: Pr Giulio Relini.

No. OU	Operative Units	Head	Zone	Surface km² (0-700 m)	Nb of hauls/year
1 IZUG	Lab. Biologia Marina ed Ecologia Animale - Istituto di Zoologia Università di Genova	Pr G. Relini	Ventimiglia Magra River	4474	40
2 CRIP	Consorzio Regionale Idrobiologia e Pesca, Livorno	Dr R. Auteri	Magra River Elba Island	8475	58
3 CIBM	Centro Interuniversitario di Biologia Marina, Livorno	Dr S. De Ranieri	Elba Island Giannutri Island	7326	50
4 DBAU	Dipartimento di Biologia Animale e dell'Uomo,- Università di Roma	Dr G.D.Ardizzone	Giannutri Island Garigliano River	9122	62
5 COISPA	Società Coop. Mola di Bari	Drssa M.T. Spedicato	Garigliano River Suvero Cape	10363	68
6 ITM	Istituto Talassografico - CNR Messina	Dr S. Greco	Suvero Cape S. Vito Cape	5771	54
7 DBAE	Dipartimento di Biologia Animale ed Ecologia - Università di Cagliari	Pr A. Cau	Sardinia Seas	26177	176
8 LBMP	Laboratorio di Biologia Marina e Pesca, Fano	Pr C. Piccinetti	Middle and North Adriatic	59000	168
9 LBMB	Laboratorio Provinciale di Biologia Marina, Bari	Pr G. Marano	Vieste Otranto Cape	15560	76
10 IZAC	Istituto di Zoologia e Anatomia Comparata - Università di Bari	Pr A. Tursi	Otranto Cape Spartivento Cape	11104	72
11 ITPP	Istituto di Tecnologia della Pesca e Pescato - CNR, Mazara del Vallo	Dr D. Levi	Sicilian Channel	52000	140
			Total	209372	964

The objective of the study was to improve knowledge not only of the structure and density of populations and their seasonal variations but also of the main biological parameters (growth, age, maturity, etc.) of the 10 target species recorded in table 3.

Three surveys per year were carried out in spring (May), summer (July) and autumn (November) in the following bathymetric strata:

- shallow water (0-50 m) targeted at red mullet *(M. barbatus)* and octopus *(O. vulgaris)*;
- continental shelf (50-200 m), targeted at lesser octopus *(E. cirrhosa)* and hake *(M. merluccius)*;
- epibathyal (200-450 m), targeted at Norway lobster *(N. norvegicus)*, deep-water pink shrimp *(P. longirostris)* and blue whiting *(M. poutassou)*;
- bathyal (450-700 m), targeted at red shrimps *(A. foliacea, A. antennatus)*, greater forkbeard *(P. blennoides)* and other large gadiforms *(M. merluccius, M. poutassou)*.

Each haul consisted of two hours of actual trawling in the deeper strata and one hour in the first stratum (because of many difficulties encountered in managing the two-hour hauls at a depth of 0-50 m where trawling is forbidden by Italian law). A period of two hours was chosen in order to collect a larger sample for better achievement of the above-mentioned objectives. Professional trawlers operating in the zone with an Italian-type otter trawl were hired.

At the end of the three-year period, the data listed in table 4 were reported to the Fishery General Directorate of MRAAF.

The performance of the gear and trawlers used during the surveys was tested for normalization of catch data by Fiorentini *et al.* (1993).

Third series of surveys (1994-1996)

Because of the delay in approval of the plan, it was decided to reduce the period to two years (March 1994 to February 1996). On the basis of a document approved during the workshop in Mazara del Vallo (16-18 March 1992; see Ragonese, 1993), all the OUs involved in trawl surveys around Italy agreed to form one group (Gruppo Nazionale Risorse Demersali: GRUND, table 5) and to follow a common protocol. All Italian seas were involved, with the exception of the Sicilian-Ionian part where trawling is difficult.

It was decided to return to stratified random sampling and the methodology employed during the period 1985-1988. Two trawl surveys were carried out, one in spring (April-May) and the other in autumn (September-October). The main objective was to update knowledge about the exploitation state of most important demersal resources. A second was to make comparisons with previous data, in particular with those of the period 1985-1988 and with MEDITS data available from 1994. The strata were the same as those of the two previous surveys, and the target species were the ten species of the period 1990-1993. In the final report to the Fishery General Directorate, the data were presented according to the headings indicated in table 4.

During the first two years of GRUND, a great effort was made to prepare a common protocol for the cruise and for the collection and processing of data. The last two stages were complicated by the fact that each OU had a different way of collecting, storing and processing data. With the aid of software experts, Operative Unit No. 10 (IZAC, Bari) and Operative Unit No. 4 (DBAU, Roma) prepared the ExtraBase (Experimental Trawl Data Base) software. This has now become the common system for GRUND, making it possible to acquire and transfer data from or to other data archives, such as that of MEDITS.

Fourth series of surveys (1996-1999)

The trawl survey project GRUND-2 began on 1st October 1996 and ended in September 1999. Two new Operative Units were involved, one dealing with gear technology and the other with methodology and statistics. The main objective was to achieve better knowledge of the exploitation conditions for demersal resources in Italian seas by means of abundance indices of species and population structure (in particular, length distribution in space and time). All hauls were concentrated into one cruise (autumn) per year, with the aim of enlarging the area to be studied and improving sampling density. This autumn survey is compared with the MEDITS spring survey. The GRUND protocol was adapted to that of MEDITS because of its better standardization. In particular, the strata (10-50 m, 50-100 m, 100-200 m, 200-500 m, 500-800 m) and locations of hauls (at least most of them) are the same as in MEDITS. It was decided not to replace the nets used in previous investigations with a new common net, so as to maintain the continuity of data. However, it was also decided to carry out selectivity tests of nets used in national programmes and calibrate surveys among commercial boats brought into operation during GRUND and those brought into operation for MEDITS, the latest using an identical net (20 mm opening in the codend).

In addition to results for the items listed in table 4, some data on the selectivity coefficient and ogives were provided for main species as well as preliminary results on intercalibration exercises. All data were referred to fished surface area (Nb/km^2, kg/km^2).

The net opening was calculated according to the formula suggested by Fiorentini *et al.* (1993).

Mapping demersal resources

Thanks to European Union funds (Project MED/91/013), twelve Operative Units worked together to map available data, in particular in relation to the ten target species from trawl surveys in 1985-1987 (fig. 1). The project was based on all collected data from 3,044 hauls. The 440 maps have now been printed (Ardizzone & Corsi, 1997) in a special volume (format A3), with funding from the Fishery Directorate of the MRAAF (now called MiPA).

The creation of a national databank from which information for various purposes can be taken (*e.g.* maps of the distribution and abundance of demersal species) is the logical result of the work carried out to date and arises from a need to complete the data on a national scale.
It was necessary to organize the available information within a single framework and achieve:
- organic collection of data;
- updating of data;
- standardization of data.
It was decided to implement a Geographical Information System (GIS) which could serve as a basis for subsequent phases of the project whose objectives were to process the data and transform them into maps.
The initial group of the Data Collecting Centre made use of existing hardware and software from the Department of Animal and Human Biology of La Sapienza, University of Rome. The system was based on Arc/Info as its main GIS package. Together with Arc/Info, Mips was used as image-processing software (both are on PC and use a Unix workstation). To allow for total compatibility with all collaborating institutions, all database management was carried out on PCs equipped with XBase-compatible software packages. Thus, data from the trawl surveys of the various OUs were collected and managed on PCs, while the Unix platform acquired basic cartographic material, analyzed data, structured and managed all geographic data. Conversion programmes ensured data flow and consistency between the two platforms. Data were checked for consistency, corrected and later converted into an Arc/Info-compatible format. As for the data relative to hauls, OUs were requested to provide the following information about each haul for the years 1985, 1986 and 1987:
- haul (peculiar to each OU);
- date;
- geographic co-ordinates (latitude and longitude ED 50);
- depth in metres;
- duration in minutes;
- total commercial yield (kg/h) for the ten target species.
In addition to general information on hauls and hourly yield, length-frequency distributions were also requested for each of the ten target species and for each haul. These data were contained in a series of files (one per species) which also included references to the hauls in which the species were caught, thus allowing for cross-referencing.
Due to differences in the boats used to conduct the surveys in the various areas (vessels of different tonnage and engine power, nets of different sizes and mesh size), data had to be standardized. As noted by Auteri *et al.* (1990), Fiorentini & Cosimi (1987), and Fiorentini & Giorgetti (1985) (for references, see Ardizzone & Corsi, 1997), the characteristics of each fishing vessel and related nets can be described using six parameters: gross tonnage, nominal engine output (Hp), otter areas, sweep length, floatline length and the circumference of the open net

(measured in terms of the number of meshes at the opening multiplied by mesh size). For our purposes, these parameters were correlated with relative average yield per hour. The following formula was used for the calculation of the standardization index (Auteri *et al.*, 1990):

$$Cst = Cre * e^{[0.290 \ln(40/LS) + 0.790 \ln(440/LSC) + 0.175 \ln(300/Hp) + 0.082]}$$

where
Cst = the standardized catch,
Cre = the real catch,
LS = the length of the floatline,
LSC = the length of the floatline plus sweeps,
Hp = nominal engine output.

Standardization coefficients were calculated for all Operative Units involved in the 1985-1987 trawl surveys (table 1) plus ICRAM.
To ensure the best use of the data, it was considered necessary to produce at least three levels of maps of varying resolution: the complete series of Italian waters on a 1:100,000 scale (49 maps), the complete series of Italian waters on a 1:250,000 scale (20 maps) and an index map of the Italian seas on a 1:1,700,000 scale.
All the data available for the following items were used:
- number and distribution of fishing ports;
- number and characteristics of trawlers per fishing port in 1987 and 1992;
- estimate of commercial product;
- distribution of the relative biomass of demersal resources obtained during trawl surveys (mainly from 1985 to 1988);
- distribution of the relative biomass of the ten target species fished during trawl surveys: *M. merluccius*, *M. poutassou*, *P. blennoides*, *M. barbatus*, *E. cirrhosa*, *O. vulgaris*, *N. norvegicus*, *A. antennatus*, *A. foliacea*, and *P. longirostris*;
- the distribution, when known, of nursery areas of the ten target species;
- the length-distribution of the ten target species in the different areas.
A new GIS project was carried out (Ardizzone *et al.*, 1998) using data collected during national experimental trawl surveys in the years 1994-1995 along the Italian coast by eleven Operative Units.
A mixed method was used to reconstruct a surface of yield data at the national level. Thirteen zones were identified, interpolation was carried out by means of universal kriging (with linear drift described by a linear function), and filtering techniques were used to extract the most relevant data points.
Maps of seasonal yield distributions and the main nursery areas of the ten target species were produced and stored on CD-Rom.

Results

The results obtained during the trawl surveys carried out from 1985 are to be found in many papers and reports (Levi & Andreoli, 1989; Operative Units Group One, 1990; Ragonese, 1993; Relini & Piccinetti, 1996). In SIBM (1994), 344 papers from 1984 to 1994 are listed together with 237 titles of grey literature. In SIBM (1998), 539 papers are reported for the period 1984-1997.
A summary of data presented by all the OUs was reported by Ardizzone (1994) in the proceedings of the meeting held in Rome (14 July 1992) at the Ministry of the Merchant Marine on the regulation of fishing effort. The national average values for efforts and yields have been plotted on a graph showing percentage variations from the average (0) of the fishing efforts and respective yields in the seas around Italy (fig. 2).
It is evident from the graph that the fishing effort per unit surface area in certain areas such as the central Tyrrhenian Sea, the southern Adriatic, northern Sicily and, to a lesser degree, the Sicilian Channel, the Adriatic and the Ionian Seas, is higher than the national average. Similarly, yields vary considerably. For the years 1985 and 1991, a global model was applied to the red mullet *(M. barbatus)*, which has a regular distribution in all Italian seas. The results (fig. 3) show very similar overall configurations in the years 1985 and 1991, but remarkable differences in weight yields (0.32 on average in 1985, 0.64 on average in 1991). For 1985, the model estimates an optimal effort of 0.66. The observed effort was 0.86, *i.e.* an excess of 23% compared to the national level. Results were practically the same for 1991, with a F_{opt} of 0.64 and an excess effort of approximately 25 per cent.
Any kind of general attempt to reduce fishing effort (not only TSL, but all forms of effort reduction such as fishing hours or days, engine power, etc.) would be much less effective than targeted actions based on the indications obtained from the models described. Differentiated reductions in each area would, in fact, be needed to achieve a certain national value.
When all data available from surveys on commercial landings (kg/h) (the share of the catch composed of commercial products to be sold on the market) for different zones are plotted on graphs, it is possible to have an idea of the trend of the landings during the period 1985-1997 (fig. 4 and 5).

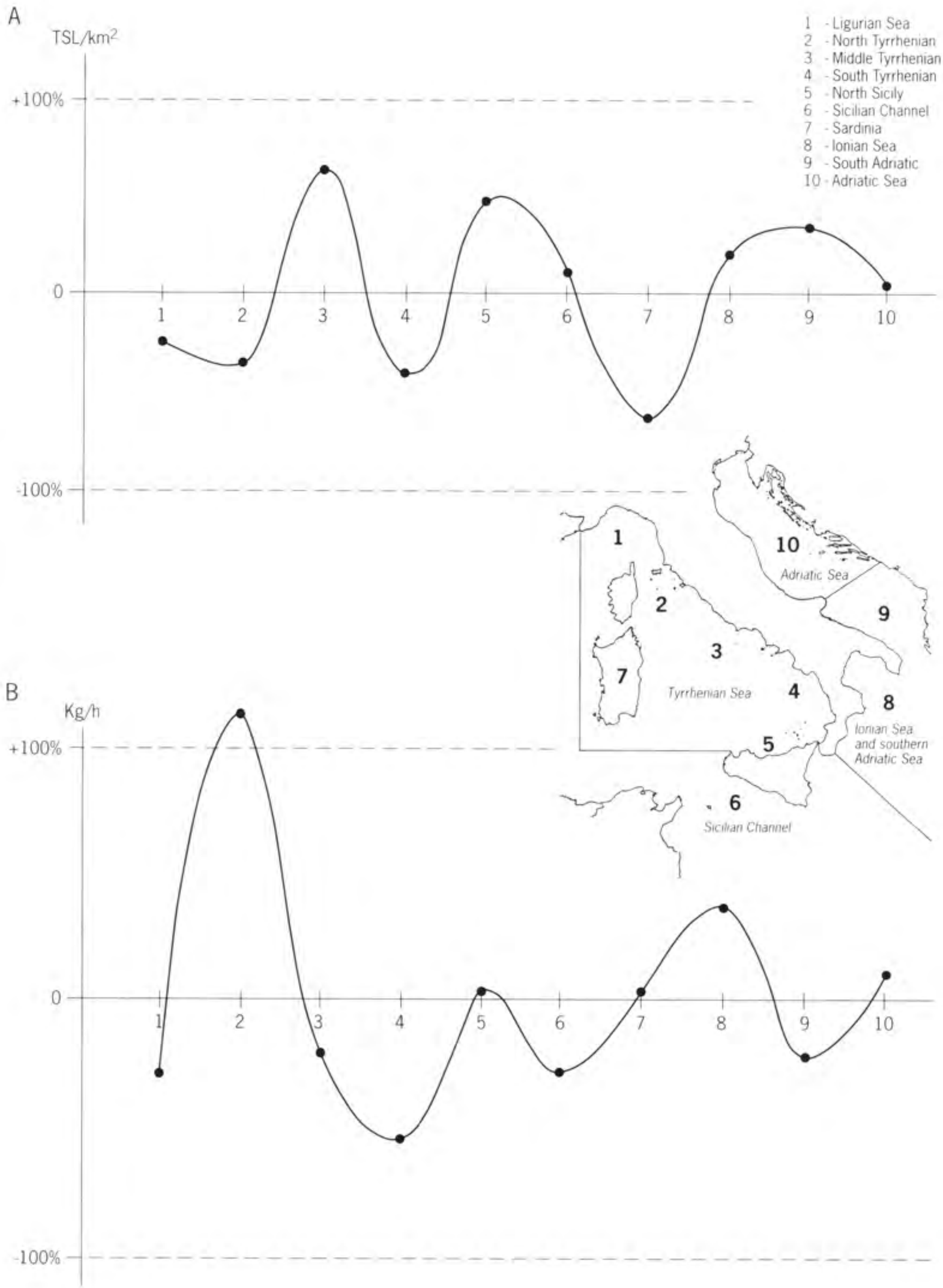


Figure 2 - Percentage variations from average (0) of fishing efforts [TSL/km^2, total gross tonnage of trawlers (A)] and of normalized yields [(kg/h) (B)] in the various Italian seas (from Ardizzone, 1994).

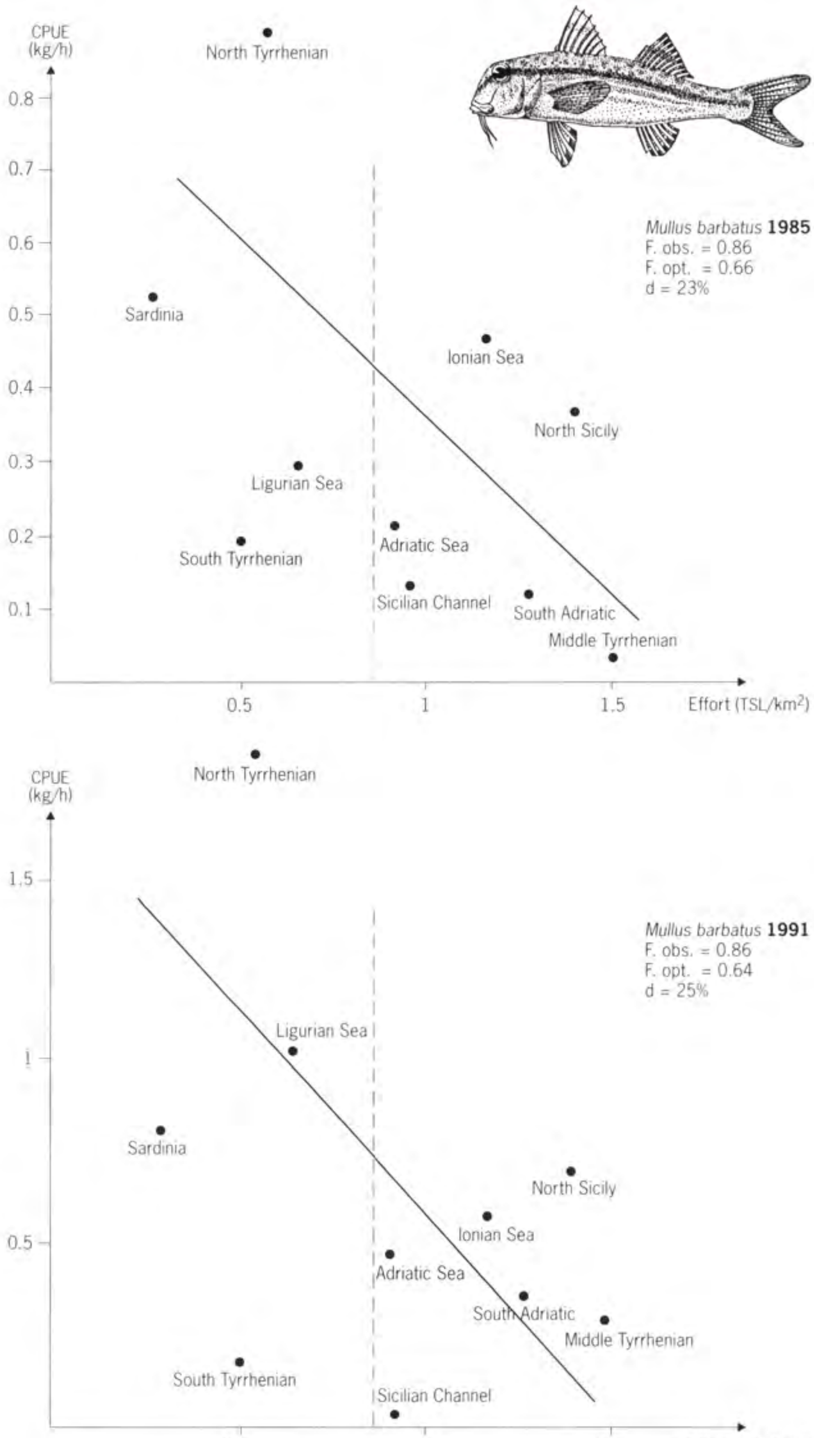


Figure 3 - Global model CPUE/Effort for *Mullus barbatus* in 1985 (above) and 1991 (from Ardizzone, 1994).

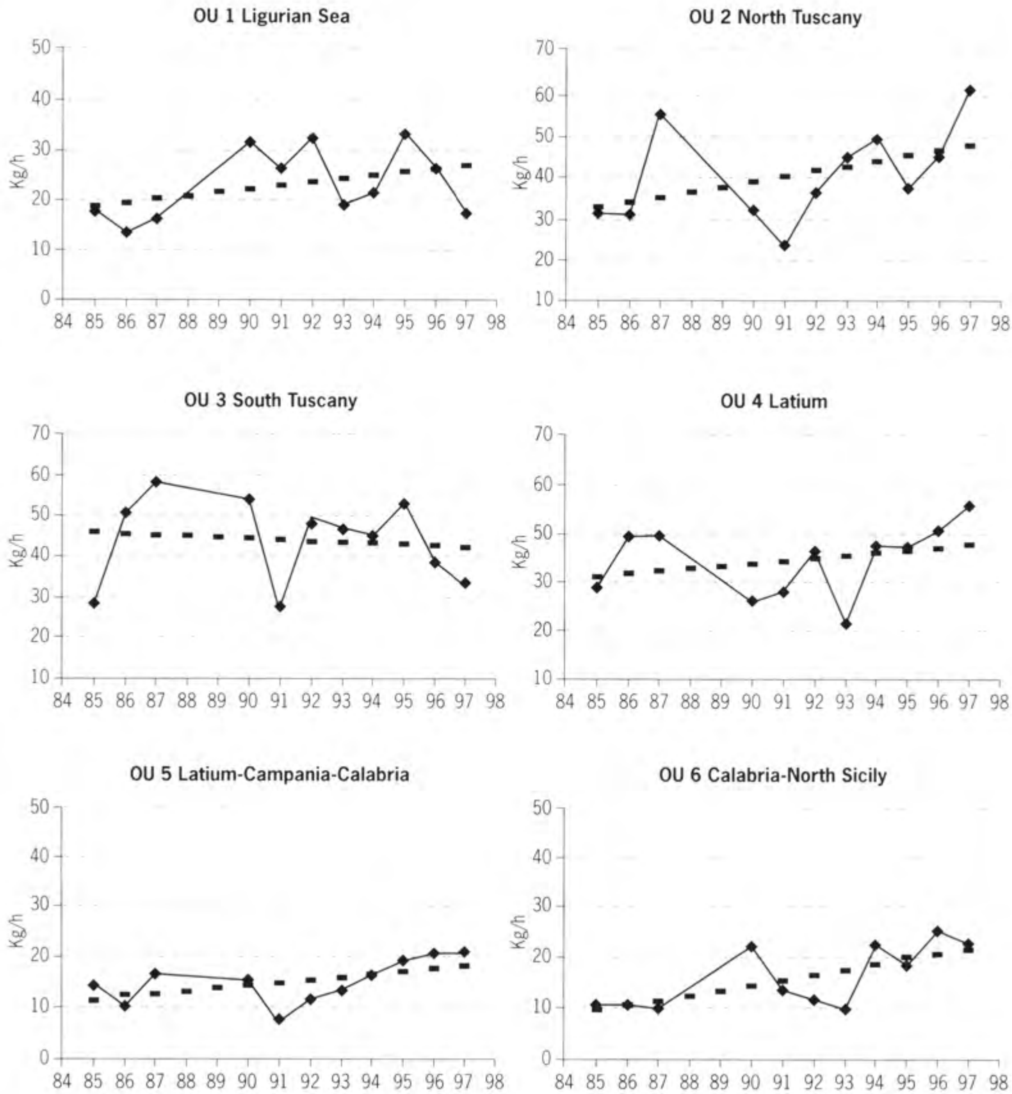


Figure 4 - Mean commercial catch (kg/h) per year and trend in the zones surveyed by Operative Units 1 to 6.

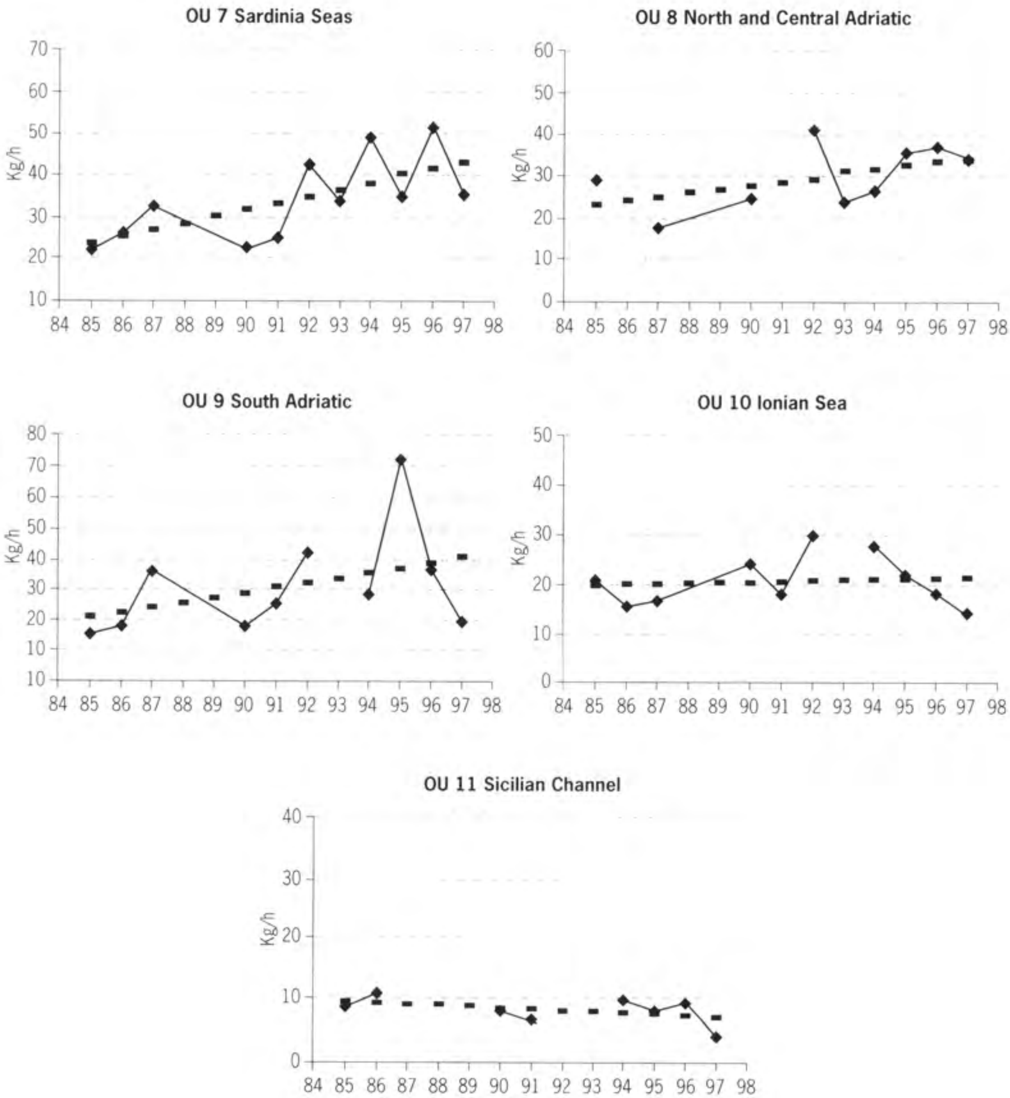


Figure 5 - Mean commercial catch (kg/h) per year and trend in the zones surveyed by Operative Units 7 to 11 (the trend is shown by a dashed line).

The survey data from 1985 to 1995 were used for the report on the central Mediterranean Sea to the Lassen Group (group of independent experts advising the European Commission on the Fourth Generation of Multi-Annual Guidance Programmes) prepared by Ardizzone and Relini in January 1996 (Ardizzone, 1998). These data were processed and grouped into four main areas in order to obtain growth parameters, size distributions and fishing mortality values for the two most important Italian demersal species: *M. merluccius* and *M. barbatus* (table 6).

Natural mortality M was evaluated using the methods of Pauly (1980) and Djabali *et al.* (1994), while total mortality was evaluated using the "catch curve" method (Pauly, 1984). $F_{0.1}$ (Beverton & Holt, 1957; Gulland & Boerema, 1973) was used as a reference of F. Finally, two values of $F_{0.1}$ were estimated with the two calculated natural mortality values, and the $F_{0.1}$ values were compared with the averages of the observed F (F_{curr}) for each area:
[% distance = (F_{curr}- $F_{0.1}$) / (F_{curr} x 100]

Table 6 - Growth parameters, natural mortality, observed mortality and reference mortality of *Merluccius merluccius* and *Mullus barbatus* in different seas around Italy.

Merluccius merluccius	K	L_∞	M (Pauly)	M (Djabali)	F_{curr}	$F_{0.1}$	% Distance
Tyrrhenian Sea	0.167	63.13	0.34	0.26	0.47	0.17	-64
Adriatic Sea	0.12	85.00	0.25	0.21	0.90	0.14	-84
Ionian and South Adriatic	0.157	68.19	0.32	0.25	0.59	0.16	-73
Sicilian Channel	0.091	80.76	0.21	0.19	0.52	0.12	-77
Mullus barbatus	**K**	**L_∞**	**M (Pauly)**	**M (Djabali)**	**F_{curr}**	**$F_{0.1}$**	**% Distance**
Tyrrhenian Sea	0.41	27.80	0.80	0.46	1.56	0.64	-59
Adriatic Sea	0.50	27.50	0.91	0.51	2.60	1.00	-62
Ionian and South Adriatic	0.313	21.72	0.69	0.41	0.86	0.76	-12
Sicilian Channel	0.154	27.60	0.42	0.28	0.60	0.60	0

Sources: Italian survey data 1985-1995. Definition of parameters (see text).

The values obtained (table 6) show a very high level of F_{curr} when compared to the reference $F_{0.1}$. They cannot be explained only in terms of overfishing. Estimates of M, L_∞ and K are probably biased, because of a different fish catchability in relation to the size of animals and the low level of calculated M. One of the main reasons is that natural mortality is not the same at different ages, as considered in the above-mentioned models (Abella *et al.*, 1997). It is noteworthy that, in spite of very high total mortality values, the length distributions of the two studied species have remained almost the same over a period of at least ten years (fig. 6-9), in particular for *M. merluccius*.

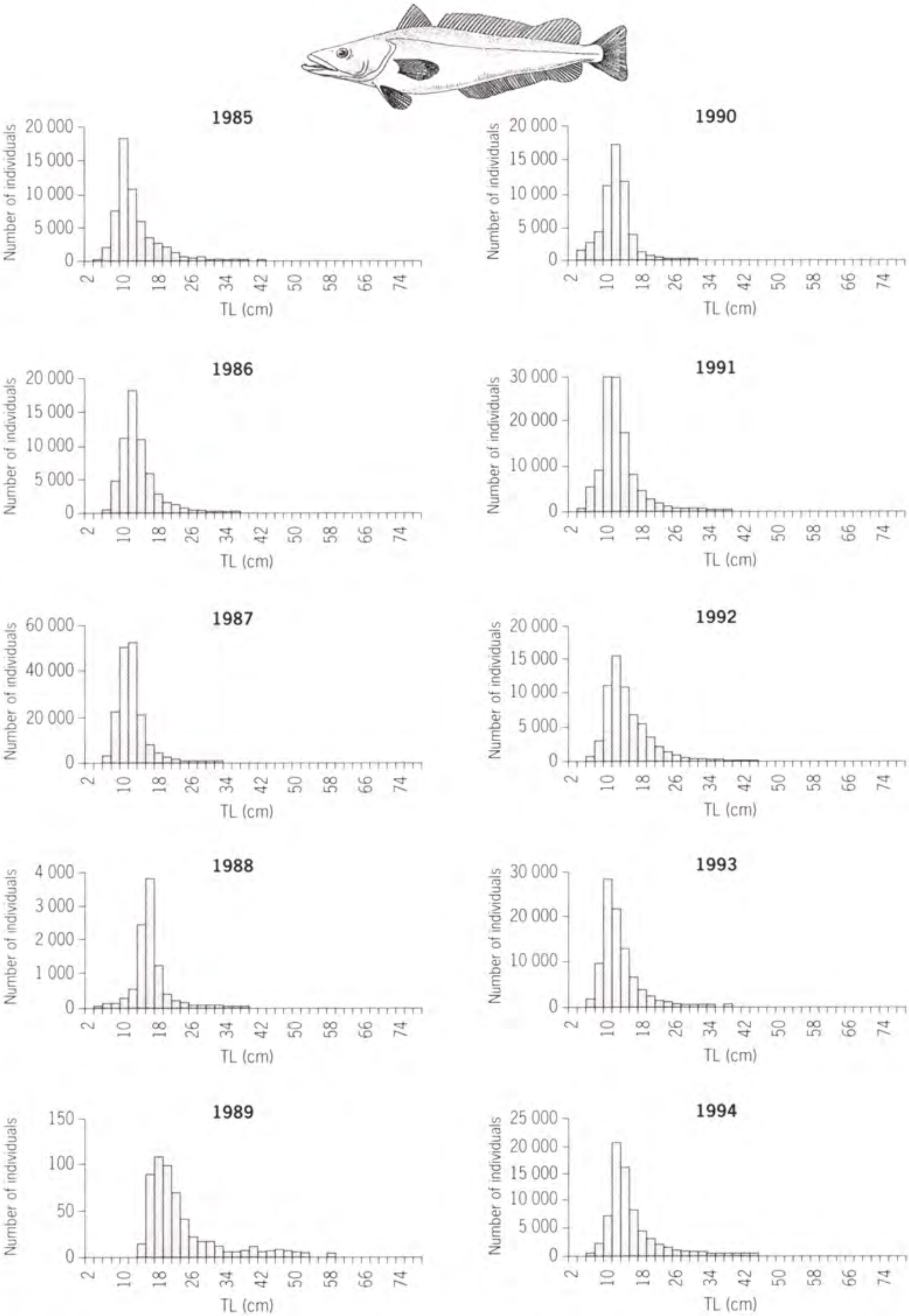
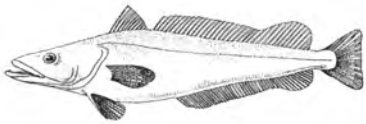


Figure 6 - Length distribution of *Merluccius merluccius* in the Tyrrhenian Sea (from the Lassen Group report, 1996).



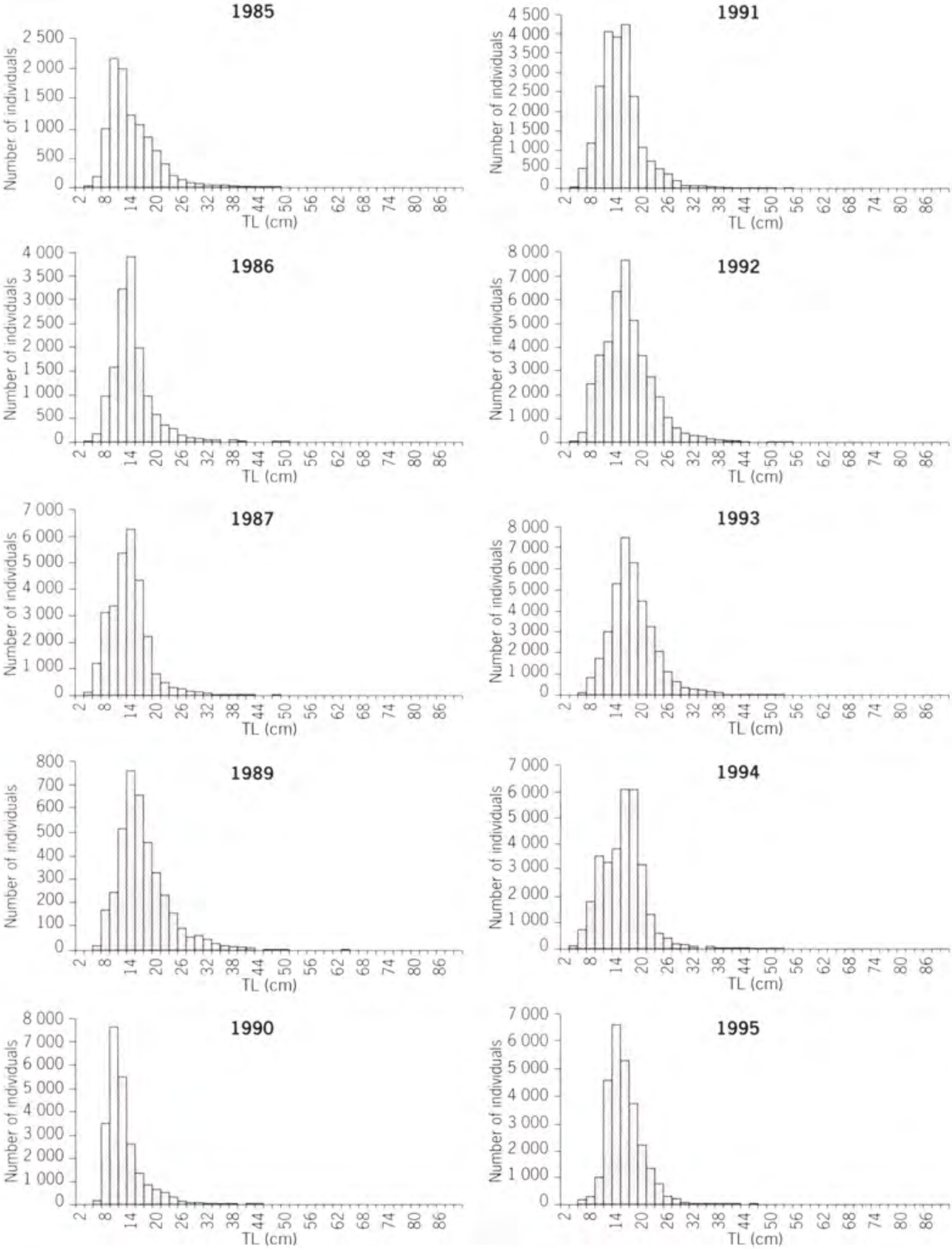


Figure 7 - Length distribution of *Merluccius merluccius* in the Ionian and southern Adriatic Seas (from the Lassen Group report, 1996).

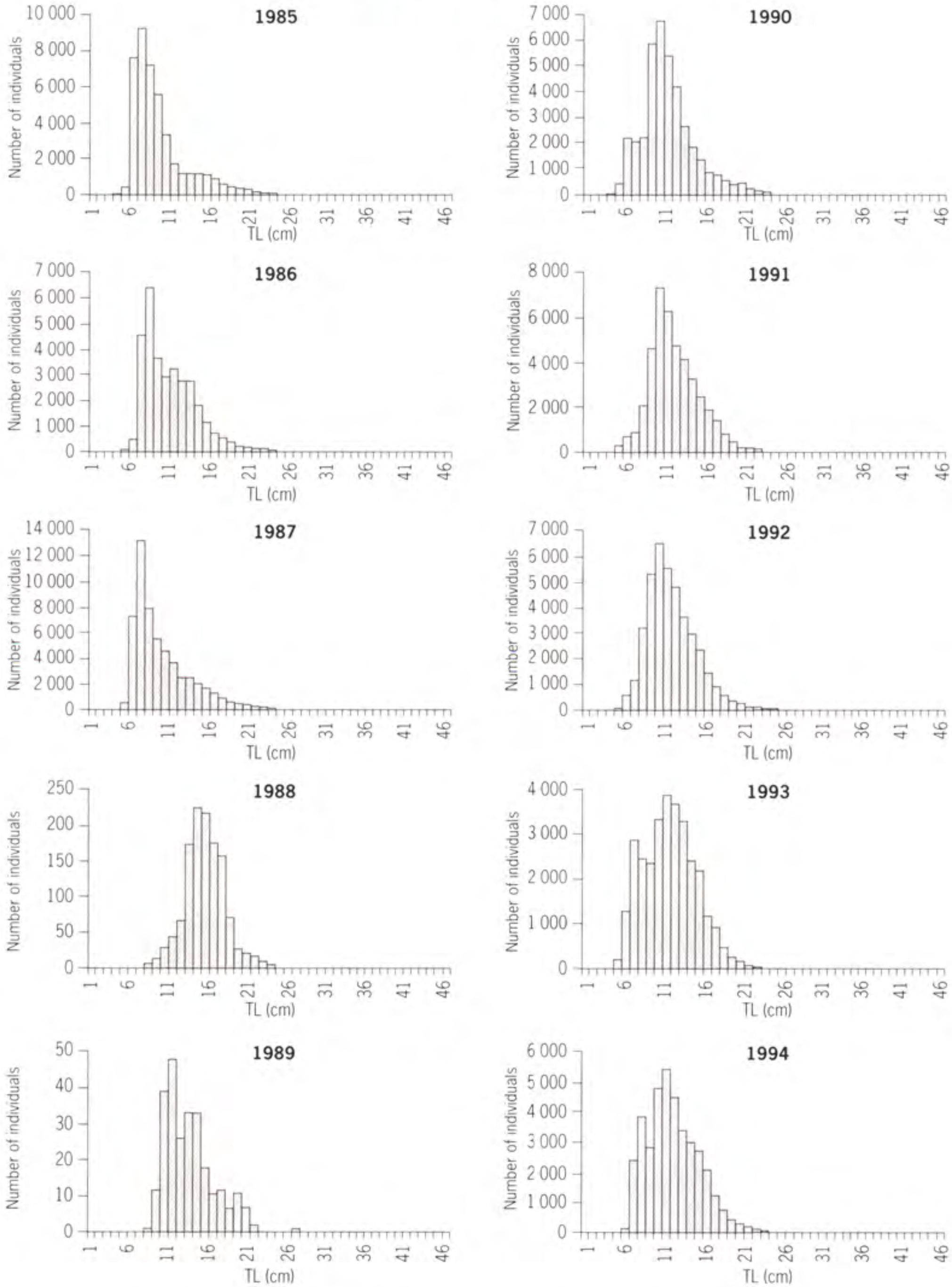


Figure 8 - Length distribution of *Mullus barbatus* in the Tyrrhenian Sea (from the Lassen Group report, 1996).

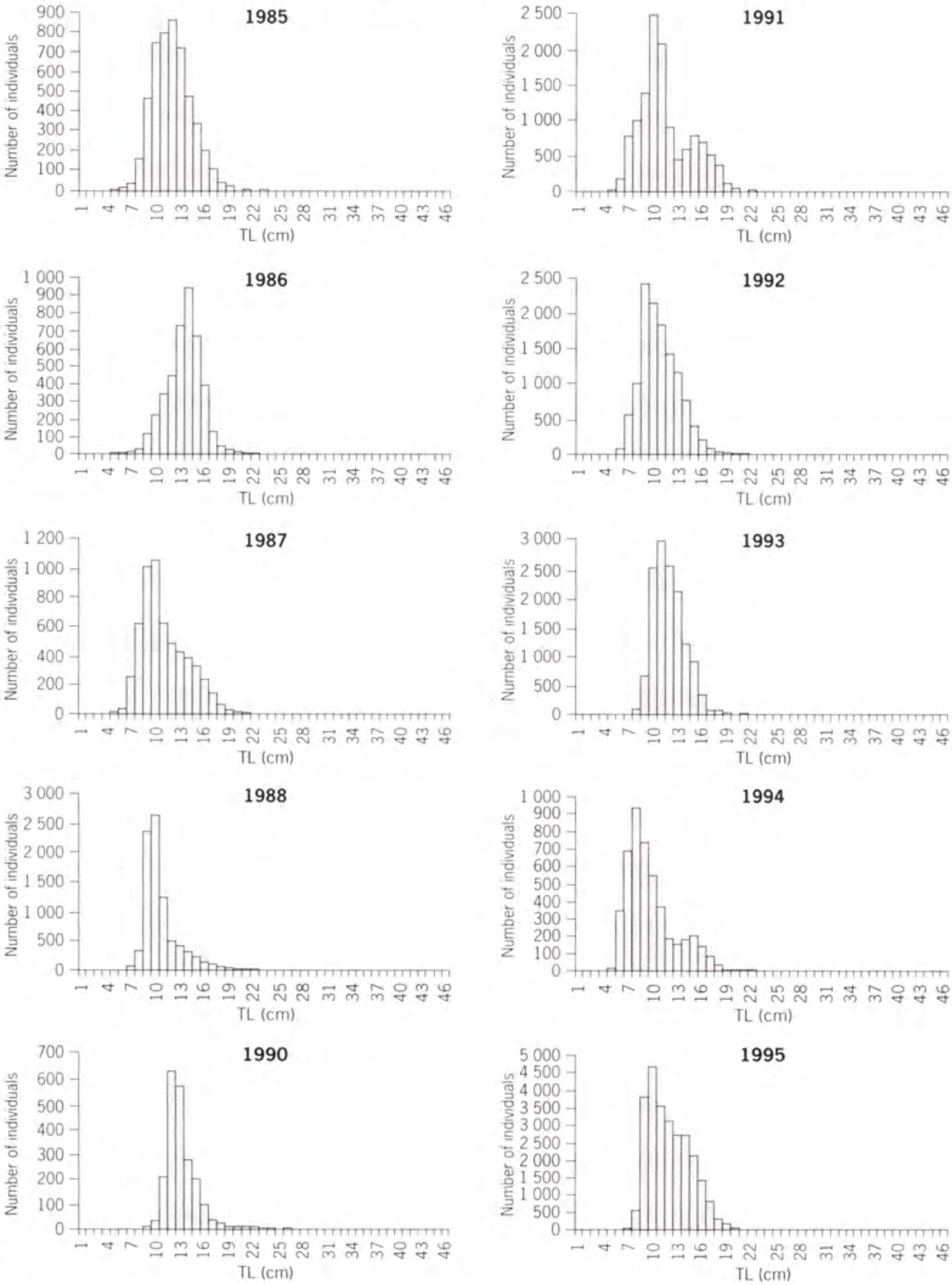


Figure 9 - Length distribution of *Mullus barbatus* in the Ionian and southern Adriatic Seas (from the Lassen Group report, 1996).

In some areas, the catch per hour has also remained quite constant (fig. 10). New models and new ideas are needed for a better understanding of the present exploitation conditions of demersal species in the Mediterranean Sea.

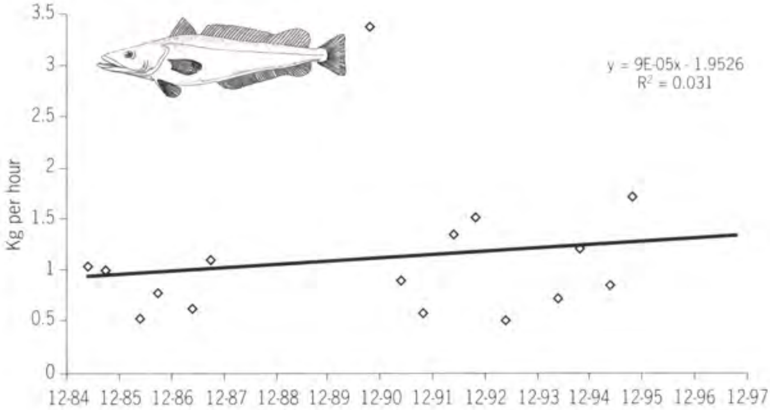


Figure 10
Catch per hour of *Merluccius merluccius* during trawl surveys carried out in the Ligurian Sea.

A tentative comparison between commercial landings and trawl survey data was made for the Ligurian Sea (Relini *et al.*, 1998), which is a field of study requiring further investigation. Standardized catches obtained from stratified trawl surveys and landings per unit effort based on the monitoring of commercial trawlers have shown that the main Ligurian demersal resources behave in different ways. Although there are no significant correlations between the two independent biomass indices obtained during the same period (with the exception of *M. barbatus*), their trends appear to be consistent with each other.

Discussion

The progress made by Italian fishery research, in particular on demersal resources, has been considerable since 1985, especially as there is no school of fishery and research co-ordinated at a national level. Thanks to Law 41/82, it was possible to organize national research, and trawl surveys were co-ordinated initially in large areas (three groups) and then in a single group (GRUND), with good co-ordination and standardization at the national level and then, after 1996, at the international level (MEDITS). As noted above, it was decided to use local professional trawlers and nets for trawl surveys in order to obtain results more similar to those of commercial fishing. A great effort was also made to standardize data collected by the different OUs through two new transversal working groups: technology of gear and boats (Fiorentini *et al.*, 1998) and statistics (Gruppo Metodologie Statistiche-GRUND, 1998). All data since 1985 have been processed and stored in a national databank allowing elaboration such as the cartography of the main demersal species (Ardizzone & Corsi, 1997). At present, twelve years of data are available for all the Italian seas, and we intend to continue collecting information in order to set up a long series through which it will be possible to have a better understanding of catch variations, population fluctuations and, if possible, trend forecasts.

Trawl survey data are used by the Central Administration (General Fishery Directorate) for management of demersal resources, in particular to intervene whenever it is urgent to reduce fishing effort and to determine the period of a "biological stop" (*i.e.* 30 to 45 days during which trawling is forbidden in large areas such as the entire Adriatic Sea). A better knowledge of nursery areas now allows the introduction of new rules to protect them seasonally or for several years, during which trawling activity will be forbidden in these zones. Studies on the selectivity of nets have provided interesting data on the minimum size of fish to be caught with different mesh sizes. A working case analysis was carried out on twelve species over short and long periods in relation to a change in mesh size. In particular, a simulated mesh opening of 66 mm at the codend and a Thompson and Bell model have been applied. Remarkable short-term losses were estimated for all species examined, while probable long-term gain was appraised for some species (see Gruppo Metodologie Statistiche-GRUND, 1998).

As the OUs in most surveys collected other species than those of purely commercial interest, our data sets could also be of considerable interest from an ecological point of view for the determination of variations over time in the natural community, fishery-environment interactions, the introduction or spreading of alien species (such as the green alga *Caulerpa taxifolia*), changes in species distribution due to probable modification of the environment (global change), etc.

In consideration of all the above-mentioned items and the high cost of trawl surveys both financially and otherwise, such cruises are very useful for collecting data not only on species of importance for the fishing industry but also on the biotic and abiotic components of the environment. Moreover, a better knowledge of the environment will help fishery management, particularly if a precautionary approach is applied for sustainable use of resources.

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Acknowledgements

The author is grateful to all the Operative Units of GRUND for constructive collaboration, and to Jacques A. Bertrand for valuable suggestions and discussions.

An international bottom trawl survey in the Mediterranean: the MEDITS programme[1]

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Abstract

An international bottom trawl survey (the MEDITS programme) has been designed from a European Commission's initiative to produce biological data on the demersal resources along the coasts of the four Mediterranean countries of the European Union (Spain, France, Italy and Greece). The main objective was to obtain independent knowledge useful for the fishery management, in an area where it is difficult to follow in detail the exploitation patterns of the fishing fleets. The programme began in 1993 and, for now, four annual surveys have been conducted. Since 1996, the programme covers almost all the Adriatic Sea owing to the participation of scientists from the Balkan countries. Involving about twenty institutes and laboratories from the seven participating countries, the programme is the first one which produces such common data at this scale in the Mediterranean, covering all the trawlable areas on the shelves and the upper slopes (at depths from 10 to 800 m) and using the same standardized protocol. During each survey, about one thousand hauls are carried out. At the end of each survey, all the data are combined and a working group produces standardized analyses on the abundance and the length distribution of around thirty reference species.

Introduction

In the Mediterranean, the main demersal fisheries are localized on narrow continental shelves along the coasts. Experiences during the last decades in this area have shown that it was difficult to obtain a global estimate of the demersal resources from fishing activity, specially due to the

1. This paper is a modified version of a paper which has been presented at the ICES Annual Science Conference in Baltimore, September 1997, with the following reference: ICES, CM 1997/Y:03.

very large dispersion of the landing places, the important diversity of the species caught and the scarceness of reliable statistics. This situation has induced different European Union States to conduct national programmes for the assessment of these resources from repetitive trawl surveys.

A lot of the demersal resources in the Mediterranean are considered as fully or over-exploited. To support the regulation of these fisheries, particularly for the application of the common fishery policy in the Mediterranean, there was a need for standardized information on the status of these resources. In this context, the European Commission has incited to the implementation of a common programme for their assessment by trawl surveys. The need for this work has been confirmed during the last Diplomatic Conference on the fishery management in the Mediterranean (Venice, 1996).

To complete this job, different institutes from the four Mediterranean European countries gathered together in 1993 to build the Mediterranean International Trawl Survey (MEDITS) programme. The characteristics of this programme are presented below.

Current objectives

The general objectives of the programme defined during an *ad hoc* working group in 1993 are the next:

"*The motivation for establishing this survey lies in the fact that comprehensive biological studies of the biological status of most of the demersal fish stocks in the Mediterranean are entirely lacking. The Commission wishes to promote such studies and one way of doing so is establish an international survey of the demersal stocks. It is hoped and expected that the collection and analysis of appropriate survey data will allow the Commission to formulate scientifically based proposals for improved conservation of the stocks*" (Anon., 1993).

From this general goal, the present programme has been designed with the following basic aims: (i) to contribute to the characterization of bottom fisheries resources in the Mediterranean in terms of population distribution (relative abundance indices) as well as demographic structures (length distributions), (ii) to provide data for modelling the dynamics of the studied species. In this scope, estimation of total mortality of the exploited species constitutes an important aim.

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

History

The general orientations of this action have been defined in 1993 by an *ad hoc* working group managed by the European Commission (Directorate of Fisheries) and opened to scientists from all the Community countries (Anon., 1993). Then the project has been formalized in the MEDITS programme which began at the end of the year 1993. At the beginning of the programme, it has been decided to call up as well as possible the competencies available in the different countries concerned by the project. So, from its beginning, the programme is managed by four main partners respectively in each of the four Mediterranean European countries, the Spanish Institute of Oceanography (IEO, Spain), the French Research Institute for the Exploitation of the Sea (Ifremer, France), the Italian Society of Marine Biology (SIBM, Italy) and the National Center of Marine Research (NCMR, Greece). Those partners have been chosen for their own competency and their ability to mobilize at national level the technical and financial means required for the programme. In each of the countries, regional co-ordinations are defined when necessary. A general co-ordination is assumed by one of the four main partners (Ifremer since the beginning of the programme till now). Since 1996, the activity of the programme has been enlarged in the Adriatic through the participation of three newcomer countries: Albania, Croatia and Slovenia. For the time being, about twenty institutes and laboratories from the northern Mediterranean contribute in the programme.

The activity of the group is managed through a Co-ordination Committee and a Steering Committee (table 1). The partners organize *ad hoc* working groups when necessary and meet once a year in a general meeting. For the time being, the programme has no formal link with other international bodies, but some of the partners are mainly involved in different other groups or organizations (GFCM, ICSEM, etc.) and other international research programmes. Those networks are used to favour exchanges of information and collaboration in the area.

One of the main challenges of the programme was to define and apply standardized protocols for the whole area, despite the great diversity of situations encountered. For this reason, the co-ordination group defined in detail a common protocol to conduct the surveys in the different areas. Then, one survey has been carried out each year with the same rules since 1994.

Table 1 - The MEDITS Steering Committee.

Institute	Name	Area
Ifremer (Nantes, France)	Jacques A. Bertrand	CC, general co-ordinator
IEO (Fuengirola, Spain)	Luís Gil de Sola	CC, Spanish area
NCMR (Athens, Greece)	Costas Papaconstantinou	CC, Greek area
SIBM/IZUG (Genoa, Italy)	Giulio Relini	CC, Italian, Albanian, Croatian and Slovenian areas
Ifremer (Sète, France)	Arnauld Souplet	CC, French area
DBAU (Roma, Italy)	Gianni Ardizzone	Ligurian Sea, North and Central Tyrrhenian Sea
DBAE (Cagliari, Italy)	Angelo Cau	Sardinia
CNR-ITPP (Mazara, Italy)	Dino Levi	South Tyrrhenian Sea and Sicilian Channel
LBMB (Bari, Italy)	Giovanni Marano	West Ionian Sea and South Adriatic Sea
LBMP (Fano, Italy)	Corrado Piccinetti	North and Central Adriatic Sea
NIB (Ljubljana, Slovenia)	Stanko Cervek	North-East Adriatic Sea (Slovenia)
IOR (Split, Croatia)	Stjepan Jukic-Peladic	Central-East Adriatic Sea (Croatia)
MAF (Tirana, Albania)	Alexander Flloko	South-East Adriatic Sea (Albania)
NCMR (Athens, Greece)	Chrissi-Yianna Politou	Argosaronic Gulf and East Ionian Sea
IFR (Kavala, Greece)	Argyris Kallianotis	North Aegean Sea
IMBC (Iraklion, Greece)	Georges Tserpes	South Aegean Sea

CC: Co-ordination Committee.

Technical description

Even when they had yet organized their own regional or national survey series (Liorzou *et al.*, 1989; Relini, 2000) and when important improvements were introduced compared with theirs, all the partners accepted to fully adopt the new standardized protocols defined for the MEDITS surveys. These standardized protocols include the sampling gear (feature and handling), the design of the survey, the information collected, the management of the data as far as the common standard analysis of the data. Before the first survey, all the common protocols have been brought together in a "Manual of protocols" (Anon., 1998) agreed by the Steering Committee and distributed to the participants. This manual has been established from different experiences, and particularly the one of the IBTS Group (Anon., 1992). The protocols have been amended when necessary for the following surveys.

Limits of duties

The working zone is defined as the totality of the trawlable areas off the coasts of the partners' countries (fig. 1), by depths from 10 m to 800 metres. These limits have been adopted to cover at best the distribution areas of the main exploited - or potentially exploitable - species, considering the administrative and technical constraints of the project.

Figure 1
The MEDITS area in 1996 (dark grey; circle: location of the main partner institutes).

Sampling gear design

All the hauls are carried out using the same sampling gear. The adopted gear (fig. 2) constitutes a compromise between the different constraints mentioned above.

To increase the catch of demersal species, it has a vertical opening slightly superior to the most common professional gears used in the area. The design of the gear has been drawn up by fishery technologists (Dremière, Ifremer Sète) from specifications defined by the biologists. The gear has been tested from a model in an artificial flume then in full-size at sea, before its production for the first survey. Then, specific studies have been conducted to complete the knowledge about the efficiency of the gear (Fiorentini & Dremière, 1996; Fiorentini *et al.*, 1999; Dremière *et al.*, 1999).

Sampling plan

The stations are distributed applying a stratified sampling scheme with random drawing inside each stratum. The stratification parameter adopted is the depth, with the following bathymetric limits: 10, 50, 100, 200, 500 and 800 metres (fig. 3). Each position has been selected randomly in small sub-areas defined so as to get a compromise between the constraints of statistics based on random sampling and those of geostatistics (Green, 1979; Hilborn & Walters, 1992).

The foreseen average sampling rate is one station per 60 square nautical miles in all the areas except in the Adriatic where it is laid down to one station per 200 square nautical miles because of the relative monotony of the substratum. The same positions are visited each year. A total of about one thousand hauls are carried out during each annual survey (tab. 2). An example of final sampling rate is given in table 3. The duration of the hauls is fixed to half an hour on depths less than 200 metres and one hour on more important depths.

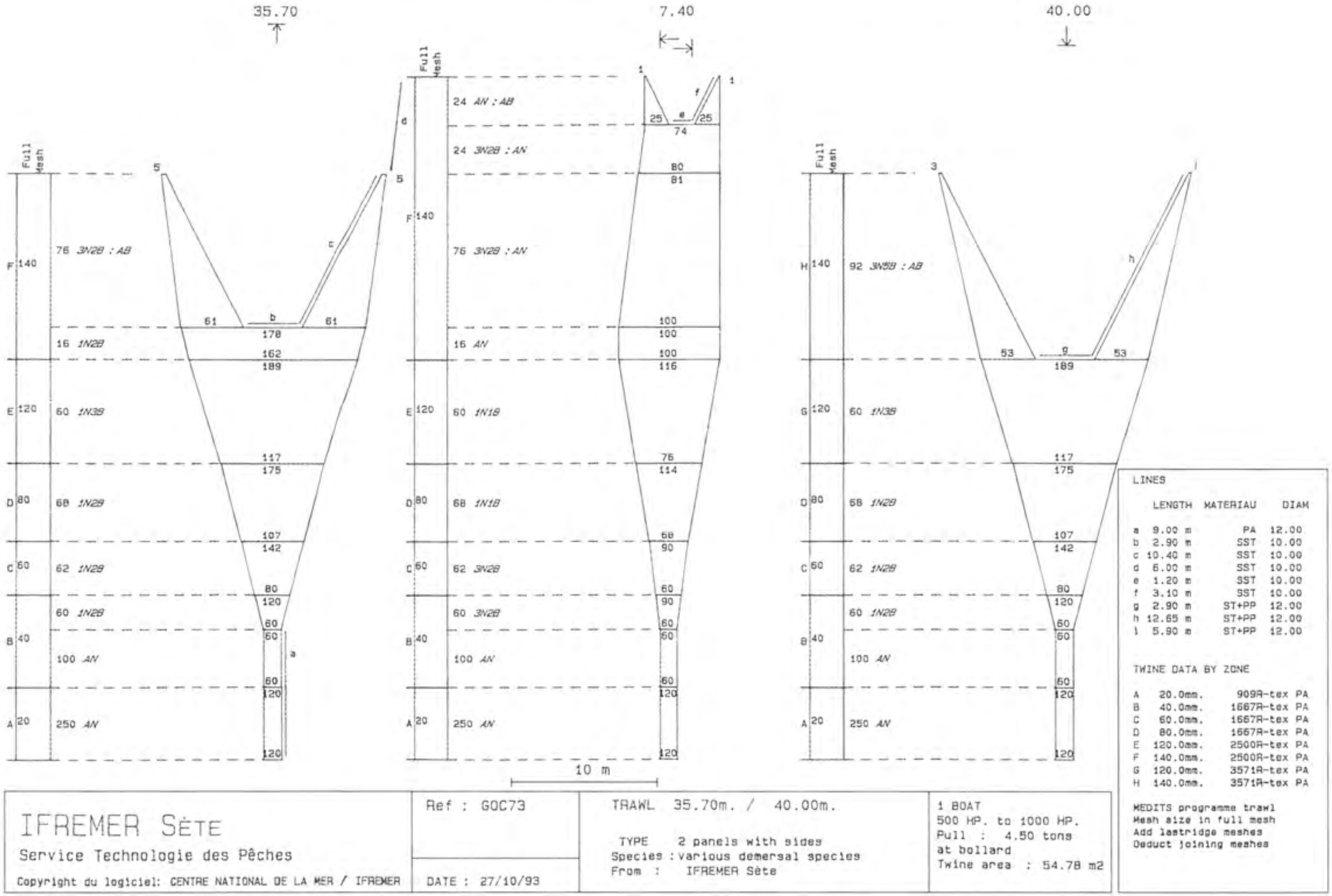

Figure 2 - MEDITS sampling gear.

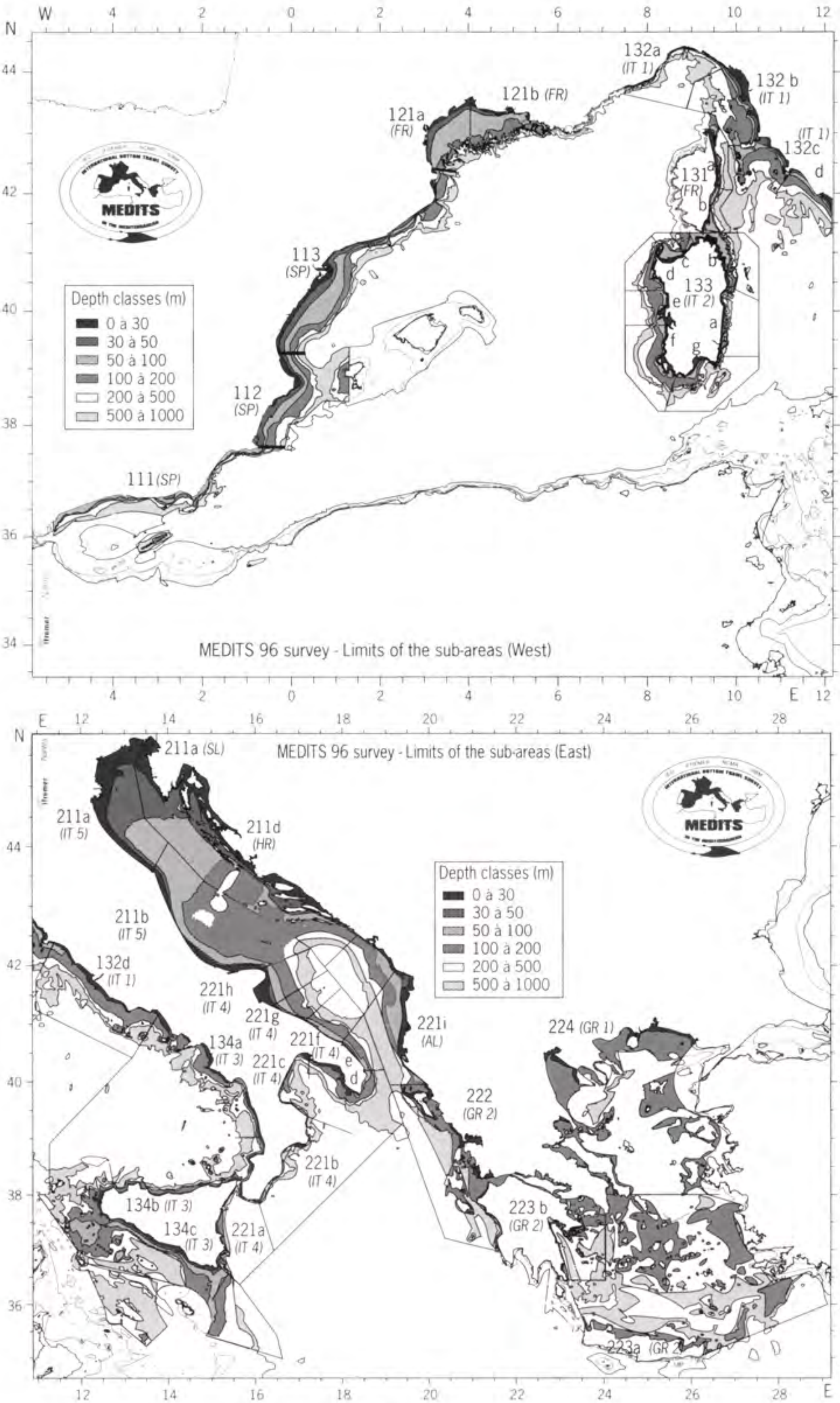

Figure 3 - Limits of the sampling strata since 1996.

Table 2 - Number of hauls during the MEDITS 94, 95, 96 and 97 surveys.

	1994	1995	1996	1997
Spain	83	111	107	102
France	94	90	89	89
Italy 1	153	153	153	153
Italy 2	124	108	125	126
Italy 3	140	142	141	141
Italy 4	146	146	146	146
Italy 5	86	88	85	86
Slovenia	-	-	2	2
Croatia	-	-	50	53
Albania	-	-	40	40
Greece 1(1)	110	120	64	64
Greece 2	-	-	93	100
Total	**936**	**958**	**1 095**	**1 102**

(1) The Greek area has been shared in two parts from the MEDITS 96 survey. The values for 1994 and 1995 are those for the total Greek area.

Table 3 - MEDITS 96: sampling scheme on the different strata (including the surface of the strata, the haul numbers and the sample rates).

	Area	No. strata	10-50 m		50-100 m		100-200 m		200-500 m		500-800 m		Total (S, nb and %)	
SP	111a	01-05	510	2	2081	5	1218	3	3682	11	5262	13	12753	34
				0.0171		0.011		0.0138		0.0277		0.0219		0.021
	112a	01-05	1130	3	4095	10	3302	6	4242	6	3159	5	15928	30
				0.0109		0.0105		0.0076		0.0111		0.0114		0.01
	113a	01-05	1896	4	7219	17	3587	9	2477	7	1399	6	16578	43
				0.0075		0.0089		0.0092		0.0182		0.0273		0.012
FR	121a	01-05	1482	8	3911	22	819	2	709	4	660	4	7581	40
				0.0251		0.0271		0.0135		0.0632		0.0542		0.031
	121b	06-10	696	4	2610	10	1734	8	653	2	586	1	6279	25
				0.0266		0.0161		0.0239		0.0293		0.0147		0.021
	131a	01-05	166		521	3	234	2	920	5	867	3	2708	13
				0.0000		0.0271		0.0217		0.0603		0.0433		0.041
	131b	06-10	0		524	3	153	3	383	3	960	2	2020	11
				0.0000		0.0287		0.0737		0.0911		0.0211		0.04
IT1	132a	01-05	657	2	729	3	658	3	1737	7	2093	9	5874	24
				0.0146		0.0177		0.0229		0.0381		0.0425		0.033
	132b	06-10	2053	8	1598	6	3186	13	2449	10	879	4	10165	41
				0.0183		0.0194		0.0200		0.0349		0.0460		0.025
	132c	11-15	945	4	1506	6	2732	10	2828	11	3071	11	11082	42
				0.0232		0.0215		0.0184		0.0381		0.0336		0.028
	132d	16-20	2107	6	2159	6	4302	13	3573	12	3148	9	15289	46
				0.0124		0.0131		0.0154		0.0343		0.0286		0.022
IT2	133a	01-05	822	3	382	2	351	2	589	3	502	3	2646	13
				0.0153		0.0236		0.0233		0.0428		0.0528		0.031
	133b	06-10	910	4	1592	6	839	2	765	3	855	4	4961	19
				0.0170		0.0156		0.0111		0.0397		0.0418		0.023
	133c	11-15	627	3	796	3	512	3	500	2	242	1	2677	12
				0.0200		0.0166		0.0286		0.0356		0.0278		0.024

	Area	No. strata	10-50 m		50-100 m		100-200 m		200-500 m		500-800 m		Total (S, nb and %)	
IT2	133d	16-20	431	2 0.0190	541	3 0.0188	896	4 0.0172	471	2 0.0231	335	3 0.0804	2674	14 0.027
	133e	21-25	1096	4 0.0133	446	2 0.0178	927	5 0.0194	412	2 0.0434	260	3 0.1075	3141	16 0.027
	133f	26-30	783	2 0.0102	987	4 0.0158	2335	11 0.0209	1620	8 0.0465	1041	7 0.0589	6766	32 0.031
	133g	31-35	705	3 0.0120	350	2 0.0250	768	4 0.0202	1060	4 0.0346	1227	6 0.0410	4110	19 0.029
IT3	134a	01-05	1194	4 0.0144	1224	6 0.0219	2095	11 0.0255	3238	15 0.0460	5248	21 0.0387	12999	57 0.035
	134b	06-10	622	4 0.0275	1003	4 0.0178	1224	6 0.0237	1966	7 0.0360	2441	7 0.0284	7256	28 0.028
	134c	11-15	3145	4 0.0055	6610	8 0.0056	9866	10 0.0049	13424	15 0.0111	15653	19 0.0117	48698	56 0.009
IT4	221a	01-05	259	3 0.0529	224	2 0.0434	584	3 0.0255	1098	3 0.0242	1273	2 0.0142	3438	13 0.024
	221b	06-10	306	2 0.0300	278	2 0.0330	258	2 0.0335	886	3 0.0301	989	15 0.1393	2717	24 0.07
	221c	11-15	455	3 0.0317	305	3 0.0475	357	2 0.0272	972	4 0.0396	1032	3 0.0281	3121	15 0.034
	221d	16-20	677	1 0.0070	524	1 0.0101	1009	3 0.0147	874	5 0.0560	1160	12 0.0923	4244	22 0.042
	221e	21-25	261	0.0000	509	3 0.0269	1348	8 0.0289	332	5 0.1413	860	4 0.0453	3310	20 0.042
	221f	26-30	329	3 0.0442	599	3 0.0237	1809	5 0.0139	472	1 0.0190	350	1 0.0258	3559	13 0.02
	221g	31-35	290	2 0.0325	689	3 0.0222	1214	3 0.0120	260	0.0000	336	1 0.0300	2789	9 0.018
	221h	36-40	1702	9 0.0234	1307	6 0.0215	1407	7 0.0236	707	4 0.0437	492	4 0.0750	5615	30 0.03
AL	221i	41-45	568	3 0.0241	2231	10 0.0209	2186	10 0.0227	1840	8 0.0405	1910	9 0.0422	8735	40 0.03
IT5	211a	01-05	17300	25 0.0063	8200	12 0.0071							25500	37 0.007
	211b	06-10	4700	8 0.0075	10350	14 0.0062	14950	19 0.0063	3900	5 0.0112	950	2 0.0197	34850	48 0.007
SL	211c	11	184	2 0.0462									184	2 0.046
HR	211d	16-19	7308	12 0.0068	14785	18 0.0052	7225	17 0.0106	2409	3 0.0128			31727	50 0.007
GR1	224	06-10	8645	7 0.0033	8489	13 0.0057	15823	14 0.0039	19774	21 0.0090	15426	9 0.0050	68157	64 0.006
GR2	222	16-20	2916	2 0.0026	4365	8 0.0074	2536	4 0.0051	3158	4 0.0122	3848	4 0.0091	16823	22 0.008
	223a	01-05	4918	2 0.0016	4090	8 0.0073	13269	14 0.0041	18100	20 0.0083	22224	8 0.0027	62601	52 0.005
	223b	16-20	2467	2 0.0026	587	4 0.0217	7143	7 0.0037	6074	4 0.0031	8645	2 0.0017	24916	19 0.003
Total													504471	1096 0.014

S: surface area (km^2); nb: haul number; %: sample rates.

Catch sampling and data collection

A list of about thirty common target species (including fish, molluscs and crustaceans) has been adopted (tab. 4). This list of species has been established with reference to their commercial production, their accessibility for a bottom trawl and their potential interest as biological indicator. Observations on these species are the count of individuals, length frequency distribution, sex (including sexual maturity stage) and total weight. The characteristics of each kind of observation are specified in the manual of protocols (Anon, 1998). For all the other species of commercial interest (fish, crustacean and mollusc), the total number and total weight are collected for each haul. During each annual survey, a total of approximately 150 species are identified aboard each of the vessels.

Table 4 - Codes and usual names of the species included in the reference list.

Species	Code	Usual name	
		French	English
Citharus linguatula	Cith mac	Feuille	Spotted flounder
Eutrigla gurnardus	Eutr gur	Grondin gris	Grey gurnard
Helicolenus dactylopterus	Heli dac	Rascasse de fond	Rockfish
Lepidorhombus boscii	Lepm bos	Cardine à quatre taches	Fourspotted megrim
Lophius budegassa	Loph bud	Baudroie rousse	Black-bellied angler
Lophius piscatorius	Loph pis	Baudroie commune	Angler
Merluccius merluccius	Merl mer	Merlu commun	European hake
Micromesistius poutassou	Micm pou	Merlan bleu	Blue whiting
Mullus barbatus	Mull bar	Rouget-barbet de vase	Red mullet
Mullus surmuletus	Mull sur	Rouget-barbet de roche	Striped red mullet
Pagellus acarne	Page aca	Pageot acarné	Axillary seabream
Pagellus bogaraveo	Page bog	Dorade rose	Blackspot seabream
Pagellus erythrinus	Page ery	Pageot commun	Common pandora
Phycis blennoides	Phyi ble	Phycis de fond	Greater forkbeard
Raja clavata	Raja cla	Raie bouclée	Thornback ray
Solea vulgaris	Sole vul	Sole commune	Common sole
Spicara flexuosa	Spic fle	Gerle	Picarel
Trachurus mediterraneus	Trac med	Chinchard à queue jaune	Mediterranean horse mackerel
Trachurus trachurus	Trac tra	Chinchard d'Europe	Atlantic horse mackerel
Trisopterus minutus capelanus	Tris cap	Capelan	Poor cod
Zeus faber	Zeus fab	Saint-Pierre	John dory
Aristaeomorpha foliacea	Aris fol	Gambon rouge	Giant red shrimp
Aristeus antennatus	Arit ant	Crevette rouge	Blue and red shrimp
Nephrops norvegicus	Nepr nor	Langoustine	Norway lobster
Parapenaeus longirostris	Pape lon	Crevette rose du large	Deep-water pink shrimp
Eledone cirrhosa	Eled cir	Poulpe blanc	Horned octopus
Eledone moschata	Eled mos	Poulpe musqué	Musky octopus
Illex coindetii	Ille coi	Encornet rouge	Broadtail squid
Loligo vulgaris	Loli vul	Encornet	European squid
Octopus vulgaris	Octo vul	Pieuvre	Common octopus
Sepia officinalis	Sepi off	Seiche commune	Common cuttlefish

Ref.: Usual names for fish: Fischer W., Bauchot M.L., Schneider M. (rédacteurs), 1987. Fiches FAO d'identification des espèces pour les besoins de la pêche (Révision 1). Méditerranée et mer Noire. Zone de pêche 37. FAO, Rome, vol 1 et 2, 1530 p.

Data management

The data are put in computer files by the teams in charge of the survey. Three standard exchange formats (in ASCII) including normalized coding are defined (tab. 5). A specific software has been written (Souplet, 1996a) for an automatic checking of the data. This checking is done by each of the partners for its own data before their regrouping. After a second validation in the regrouping place (Ifremer Sète), duplicates of the total set of data files are deposited on diskettes at the co-ordinators and EC-DG XIV offices. A specific chart defines the rules for the distribution of the data.

Table 5 - Parameters included in the exchange files.

Haul characteristics (file A)	Catch per haul (file B)	Biological parameters (file C)
Country	Country	Country
Vessel	Vessel	Vessel
Gear	Year	Year
Rigging	Haul number	Haul number
Doors	Codend closing device	Codend closing device
Year	Part of the codend	Part of the codend
Month	Faunistic category	Faunistic category
Day	Species code (rubbin)	Species code (rubbin)
Haul number	Total weight in the haul	Length class code
Codend closing device	Total number in the haul	Fraction weight
Shooting time	Females number	Subsample weight
Shooting quadrant	Males number	Sex
Shooting latitude	Unsexed number	Number of measured individuals
Shooting longitude		Length class
Shooting depth		Maturity
Hauling time		Number of individuals in that class
Hauling quadrant		
Hauling latitude		
Hauling longitude		
Hauling depth		
Haul duration		
Validity code		
Course (rectilinear or not)		
Species reporting code		
Distance		
Vertical opening		
Wing opening		
Briddles length		
Warp length		
Warp diameter		
Hydrological station number		
Observations		

Since 1997, an outstanding project is in growing to develop a database for a full management of the MEDITS data (EC-DG XIV project 96-016). The objective is to constitute a unique database and common statistical algorithms to serve the demand of the MEDITS programme.

The main functions will be the control-validation of the data before storing, the storage of the data, their exploitation using standard statistics and the performance of specific requests. This new tool has been made available to the group in 1999.

Data analysis

At the end of each survey, standard analyses are produced on the data. These analyses include the production of biomass and abundance indices (in kg/km^2 and in nb/km^2) as well as length frequency distributions for each of the reference species and each of the strata. These analyses are made using classical statistical method approved by the Steering Committee. Specific softwares have been written for computerization of calculations (Souplet, 1996b) and standardized result presentation.

Frequency

The present objective is to conduct one survey per year. This yearly survey occurs during the spring and the beginning of summer. One common MEDITS survey has been carried out each year since 1994 till 2000. A working group is organized after each survey for a common analysis of the results and the estimators produced from the survey series.

Scientific effort

Each survey has been carried out aboard eight or nine vessels, according to the year. Each of those vessels works at sea during about one month per year. Research vessels and chartered fishing vessels are used depending on the local possibilities. The organization of the work at sea mainly depends on the facilities given aboard the vessels. In some cases, the samples are only taken and preserved on board and all the biological analyses are carried out in the laboratories. On the contrary, in other situations, particularly aboard the research vessels, the whole analysis of the samples, including the data input in computer files, are conducted aboard. Generaly speaking, it is considered that the MEDITS survey mobilizes five equivalent scientist-days (at sea or in the laboratories) for one vessel-day at sea.

Use of survey information

The results of the surveys are used mainly at two levels by the scientists involved in the programme. At a general level, a global description on the distribution of the reference species is produced. This information is given from abundance and biomass indices for each species (fig. 4 and 5) as well as their length distribution by stratum. Another objective is to use this information to estimate demographic parameters like recruitment and mortality. Nevertheless, for the moment, the series was considered too short to introduce such analyses.

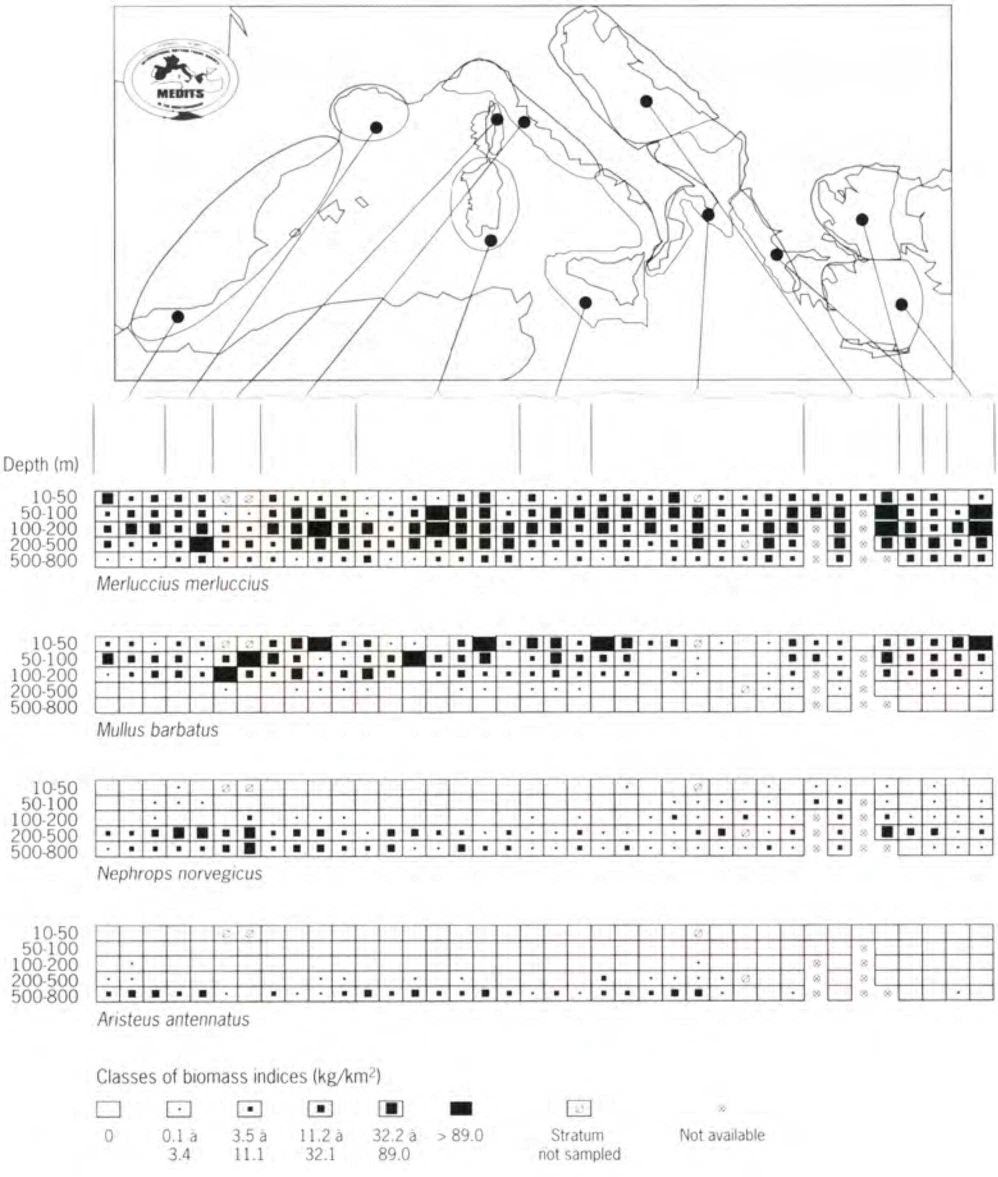

Figure 4 - MEDITS 95, 96 and 97. Mean biomass indices by strata for some species.

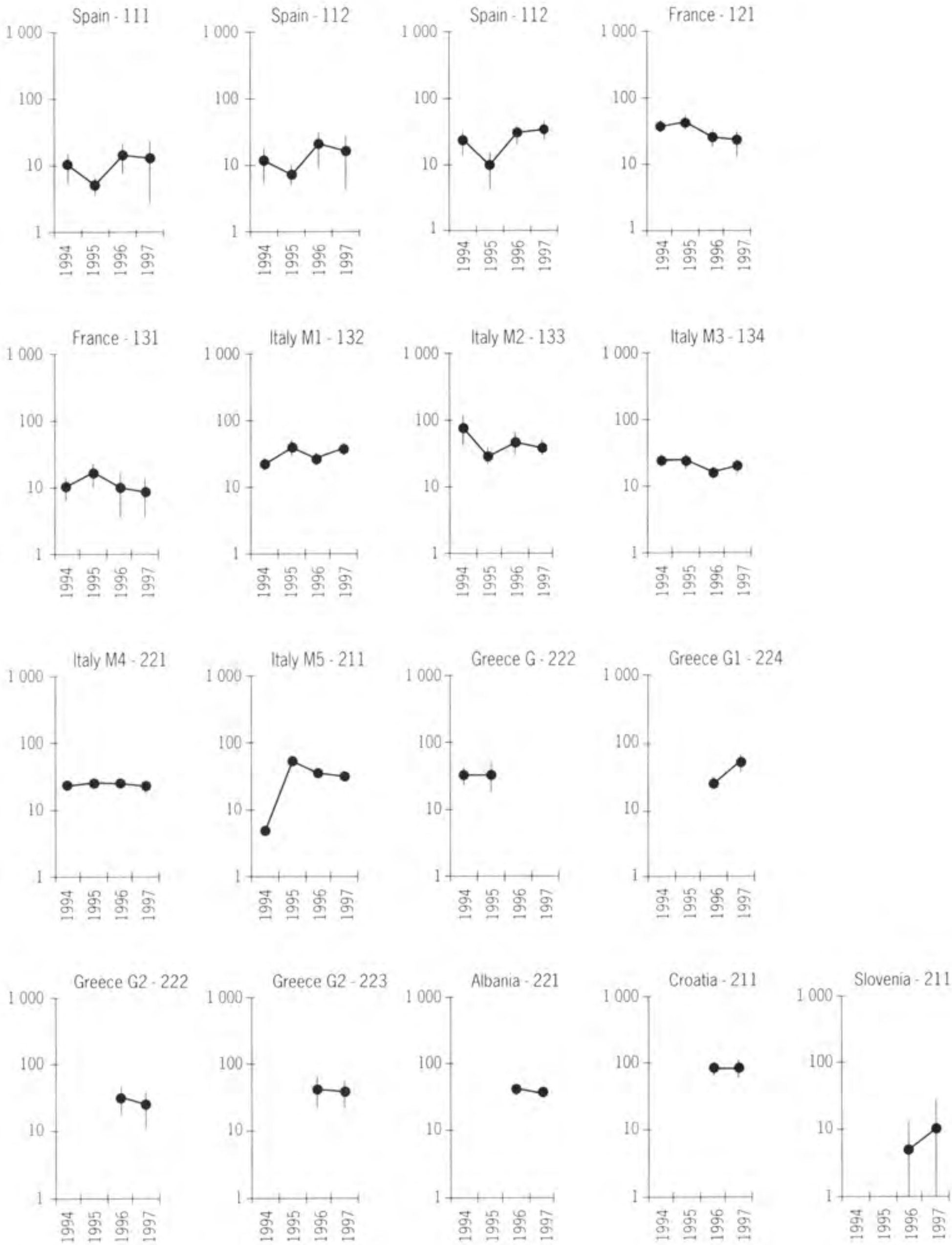

Figure 5 - Biomass indices (kg/km^2) for *Merluccius merluccius* by main areas from the MEDITS surveys 1994-1997.

In the different sub-areas, the MEDITS results are introduced in various analyses. For instance, they have been added in a composite series of trawl surveys, from 1957 to 1995, to study the biodiversity trend of the demersal species in the Gulf of Lions (Aldebert, 1997). In some places, they are used to study the structure of demersal fish communities and more generally to analyse the spatial distribution of the species by different spatial methods (Lembo *et al.*, 1997; Corsi *et al.*, 1997). It is also proposed to use the MEDITS data for preliminary stock assessments by composite production models.
Apart from the biological observation, trawl surveys constitute an opportunity to assess the human refuses on the shelves and slopes (Galgani *et al.*, 1996).

Resulting reports and publications

From the beginning of the programme, all the basic information related to the programme is presented in annual reports (Bertrand *et al.*, 1994, 1995, 1996, 1997). Generally, these reports comprise two main parts. One part describes in detail the technical organization of the surveys with a general information on the survey progress aboard each of the vessels, a description of the vessels used, the survey calendar, the lists of the scientists who took part in the survey aboard each vessel, a presentation of the final sampling scheme as well as the meeting reports. The common biological results including formal description, data tables and length distribution graphs are grouped in a second part of the reports. This information is completed with the bringing up to date of the manual of protocols, when necessary.
These results may be used as material for different publications, *e.g.* when producing syntheses of knowledge on the demersal resources in the area (Relini *et al.*, 1999). Other results obtained by the different teams from the MEDITS data are presented and diffused through their usual channels.
To reinforce the communication and the diffusion of the results obtained from the programme, the MEDITS partners decided since 1996 to organize the present symposium on "*Assessment of demersal resources by direct methods in the Mediterranean and the adjacent seas*", allowing to incorporate four annual MEDITS surveys. It was anticipated that this meeting will favour relationships between the scientists involved in different research surveys programmes and in different analytical approaches.

Discussion and conclusion

Regarding the reach of the objectives and the prospect of the programme, the following points may be highlighted.
The MEDITS programme was the first one in the Mediterranean where a collaboration was developed at such a scale and in such an integrated way for the assessment of the demersal resources. Particularly, with the

production of a common databank, the partners have created the basis for a common working framework. The results obtained so far are very promising.

So, at the time when the officials intend to harmonize the fishery regulation in the Mediterranean, the standardization adopted inside the MEDITS programme makes possible from now to introduce a general description for most of the demersal resources all along the coasts of the four Mediterranean European countries as well as in the Adriatic Sea. The first surveys gave very interesting information for the description and the production of general indicators concerning the demersal resources, particularly on their distribution in the different areas. For the time being, the series was yet too short to permit a full analysis of the data obtained, especially for time trend analyses. Nevertheless, it is anticipated that the present symposium will offer an opportunity to progress to this aim. This meeting also gives a chance for a debate on the future of the programme.

Naturalists have mainly to take part in the trawl surveys, particularly to ensure the quality of the biological data introduced in the databanks. Statisticians, data analysts, fishery biologists are also strongly required to contribute in the valorization of surveys. One of the challenges for the research survey programmes is to favour a well-balanced collaboration between these different specialists. This is particularly important to give the best conditions for the continuation of the surveys. Inside the MEDITS programme, different attempts have been done to favour this kind of collaboration (working groups, etc.). It is expected that the present symposium will contribute to progress on that question.

Till now, the common data collection inside the MEDITS programme has been focused on biological data. For the future, it is expected to include the collection of basic environmental data (particularly temperature) in the standard observations at each station.

The MEDITS Steering Committee is preoccupied with the intercalibration between the different vessels. This question is all the more important because each of the vessels has to work in an independent area. During the last few years, the Italian partners have carried out a national and the international MEDITS surveys concurrently in same areas. As they have started a peculiar study for the calibration between the different vessels and methods used, the MEDITS group is waiting for the result of this work before further reflection.

The EC-DG XIV initiative has been a deciding factor for the establishment of the MEDITS programme. The first results obtained inside the programme can be considered very encouraging. Till now, the programme is supported through a structure of short duration research contracts. This organization does not offer the best conditions to manage lasting data collection. For the future, the need for a stabilized common management structure would be considered.

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Acknowledgements

The MEDITS programme is conducted thanks to the incitement and financial support of the European Commission (Directorate of Fisheries) jointly with the contribution of the partner countries.

Chapter II

Data analysis methodology

Geographical Information Systems and Surplus Production Models: a new model for spatial assessment of demersal resources

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Abstract

Geographical Information Systems (GIS), with their ability to manage large amounts of data, make it possible to investigate the behaviour of Surplus Production Models in conditions of varying stock densities. Using the data derived from experimental trawl surveys conducted within the framework of the MEDITS project from 1994 to 1996, in this paper the distribution of catch per unit effort data is estimated throughout the study area (North and Central Tyrrhenian Sea). A similar distribution is also produced for the effort data using a deductive approach. The two data sets are then analyzed through a scatter plot which reveals a possible density dependent pattern in the applicability of the Schaefer Surplus Production Model. The pattern is evidenced using the Schaefer model fitted to the average CPUE and effort of the ten main fisheries which operate in the study area. Based on this last analysis and on a derived model which identifies areas under different conditions of exploitation, two maps are derived: one of homogeneous stock densities and another of over-exploited and under-exploited areas.

Although caution is expressed in the conclusions, especially as regards some simplifications used in applying the models, the overall result has a sound biological interpretation and seems quite promising as a tool for fisheries management.

Introduction

In the last few years, there have been important developments in the application of methodologies of spatial analysis such as the Geographical Information System (GIS) to faunistic data. In the case of fish resources, the spatial distribution over large areas can have great importance for exploitation management purposes.

In the same period, an increasing number of national and international experimental surveys covering important Mediterranean areas have been carried out extensively along the coasts of EU countries, providing important spatial information (Relini, 1985; Relini & Piccinetti, 1994; Bertrand *et al.*, 2000; Ardizzone & Corsi, 1997).

The idea behind this paper is to analyse whether sets of single georeferenced catch data can be used to fit the Surplus Production Models assumptions to produce a spatial stock assessment.

Surplus Production Models, generally applied to time series catch/effort data, are based on the following assumptions:

- the fishery is in an equilibrium situation, that is, after an initial stage in which the fishery exploits the virgin stock (whose dynamics is mainly defined by natural mortality and recruitment to the stock), the stock reaches an equilibrium in which the dynamics is defined essentially by fishing mortality;
- catchability (q) is constant, that is, the fishing mortality is proportional to the fishing effort (E).

Based on these assumptions, Surplus Production Models state that increasing the fishing effort will reduce the catch per unit effort (CPUE). The earliest methods involving these models used the linear regression of CPUE (or its logarithm) and the effort observed in the current and previous years (Schaefer, 1954; Pella & Tomlinson, 1969; Fox, 1970). More recent methods have included statistical refinements such as the treatment of statistical error (Polacheck *et al.*, 1993), bootstrapping (Prager, 1994) and bayesian analysis (Hoenig *et al.*, 1994).

Assuming homogeneous ecological features and little mixing between areas (*e.g.* benthic rather than pelagic species), the idea of comparing CPUE extracted per unit area between adjacent areas which are subject to different intensity of fishing effort was explored by Munro (1979), then extended by Caddy & Garcia (1982) and applied in the Italian seas for a set of important demersal species by Ardizzone (1994).

When these models are applicable, it is quite easy to define a maximum sustainable yield (MSY), which corresponds to a given effort maintainable over time so that the stock will be able to conserve its potential. However, to make the assumptions of homogeneity hold true, data must be averaged over coarser scales. In fact, it is impossible to know the exact density of the stock at any given time or in any given area in the fishery, but it is rather easy to define an average density, let's say, over one year or within a fishing zone.

Here the behaviour of Surplus Production Models is assessed at a more detailed scale, at which density must be regarded as a variable and not as a constant.

Materials and methods

Biological data on demersal resources along the coasts of the four Mediterranean countries of the European Union (France, Greece, Italy and Spain) were collected during three experimental trawl surveys carried out in the 1994-1996 period within the EC financed MEDITS programme. Fishing trawlers used in the different areas had similar characteristics and the same fishing gear. A common random stratified sampling design and sampling season was adopted to standardize the yield. Each of the 130 sampling points was georeferenced and during the three years haul locations did not change (Bertrand *et al.*, 2000).
In this paper, data of *Merluccius merluccius* collected in the North and Central Tyrrhenian Sea between Viareggio and Terracina are analyzed. This area can be subdivided according to the ten main fisheries' ports. Based on the reports of the fishermen and the experience of the scientists, the fishing areas of these ten commercial ports were acquired in the Geographical Information System (GIS).
The choice of a GIS to handle data sets was motivated by its ability to graphically display layers, combine layers, and conduct spatial analyses of georeferenced data within a layer or among the elements of two or more layers. The GIS software used for the analyses and representation of data was Arc/Info (ESRI, 1991).
For the sake of simplicity, areas of overlap between adjacent fishing zones were not taken into account, except for the areas of Castiglione della Pescaia and Piombino which fall completely within the zones of Porto Santo Stefano and Livorno respectively (fig. 1).
The entire study area was converted into a raster data set with pixel size of 1x1 km, and the same data format was used for all the layers included in the analysis. Although this level of detail may be excessive if compared to the raw data used in the analysis, it was functional to the graphic representation of the results of the analysis. For each pixel of the study area, a value was calculated for effort and CPUE based on the following models.

Fishing effort

Distribution of fishing effort within a particular area is influenced by different elements such as distance from the port, depth, weather conditions, bottom ground type, etc. Although none of these variables had been assessed through research, for simplicity the first two variables were used in this exercise to model the spatial distribution of the effort. Thus, based on the available information on the gross tonnage (GT) of the trawlers of each fishing zone within the study area (table 1), the spatial distribution of the fishing effort throughout the fishing ground was obtained, modelling the fleet's use of space with depth and distance from the port.

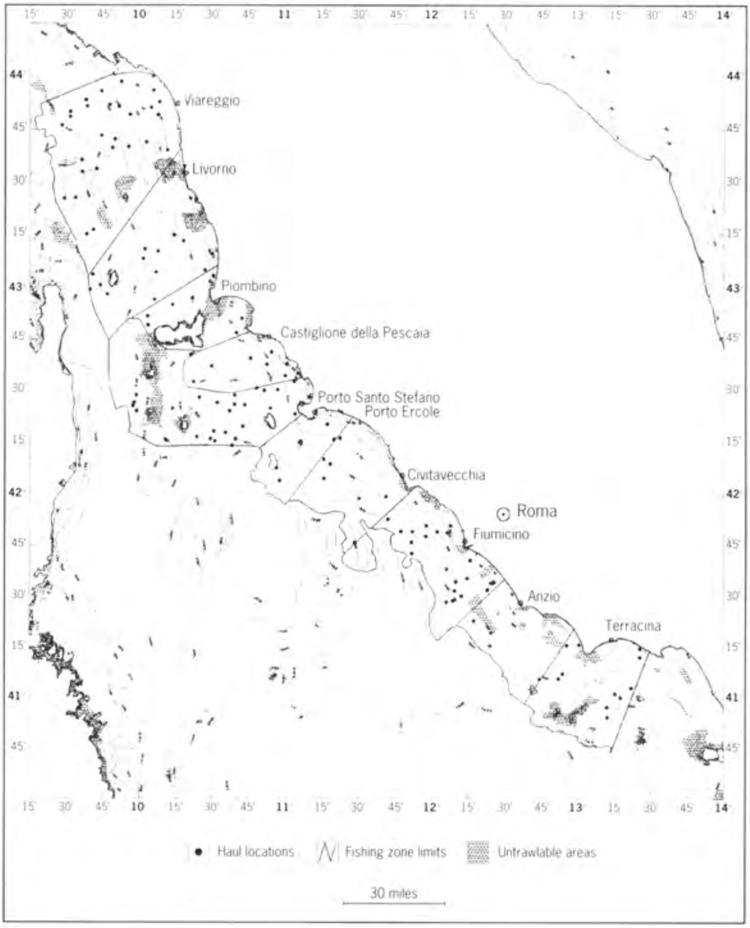


Figure 1
Study area: main ports and their fishing grounds.

Table 1 - Characteristics of the ten main fisheries of the study area. For each fishing zone are reported: size of trawlable area, gross tonnage and number of trawlers, mean fishing effort and CPUE.

Fishing zone	Trawlable Area (km^2)	Gross Tonnage (GT)	Number of trawlers	Fishing effort (GT/km^2)	CPUE (kg/h)
Terracina	2479.22	801.90	27	0.32	4.33
Anzio	1842.72	1229.19	33	0.67	2.54
Fiumicino	2692.17	1433.30	38	0.53	3.80
Civitavecchia	2327.06	1149.35	23	0.49	3.65
Porto Ercole	1375.27	594.40	11	0.43	4.41
Porto Santo Stefano	5108.96	1264.40	28	0.25	5.66
Castiglione della Pescaia	1493.64	630.62	22	0.42	3.21
Piombino	1146.87	697.93	25	0.61	2.52
Livorno	4451.95	1107.20	31	0.25	3.84
Viareggio	4844.74	1669.30	92	0.34	4.59

It was assumed that fishing effort increases moving away from the port up to a certain distance and then starts to decrease, and similarly, it was assumed that it increases up to a certain depth and then starts to decrease. Not having any direct evidence of the functions which describe the variation of the effort in respect to the two variables, a deductive approach was used. Based on the experience of one of the authors (G.D. Ardizzone), an estimate of the percentage of time spent fishing within range classes of depth and distance from the port was produced (table 2), and these were fitted by means of least square fit to various types of functions.

Table 2 - Percentage of use of space according to depth and distance from the port. These data were used to derive the models in fig. 2

Depth Range (metres)	Use (%)	Distance Range (miles)	Use (%)
0 - 10	0	0 - 2.5	2
10 - 50	5	2.5 - 5	5
50 - 100	15	5 - 7.5	15
100 - 200	30	7.5 - 10	18
200 - 300	25	10 - 12.5	20
300 - 400	15	12.5 - 15	16
400 - 500	5	15 - 17.5	10
500 - 600	3	17.5 - 20	6
600 - 700	1	20 - 22.5	4
> 700	1	22.5 - 25	3
		> 25	1

The functions which performed best (fig. 2) were used to assign a score to each of the pixels within the study area. Each pixel was given a fraction of the total effort within its fishing area, according to the following equation:

$$E_i = E_{tot} * S_i/S_{tot}$$

where:

E_i is the effort of the i^{th} pixel

E_{tot} is the gross tonnage of trawlers within the fishing zone in which the i^{th} pixel falls

S_i is the score of the i^{th} pixel according to the functions of depth and distance. For the i^{th} pixel is given by:

$$S = (S_{depth}+S_{distance})/2$$

S_{tot} is the sum of the scores of all pixels falling within the fishing zone. For each zone is given by:

$$S_{tot} = \Sigma S_i$$

Having no *a priori* assumption on the contribution of the two variables to the spatial distribution of the effort, after a few trials, the two variables were combined by a simple arithmetic mean.

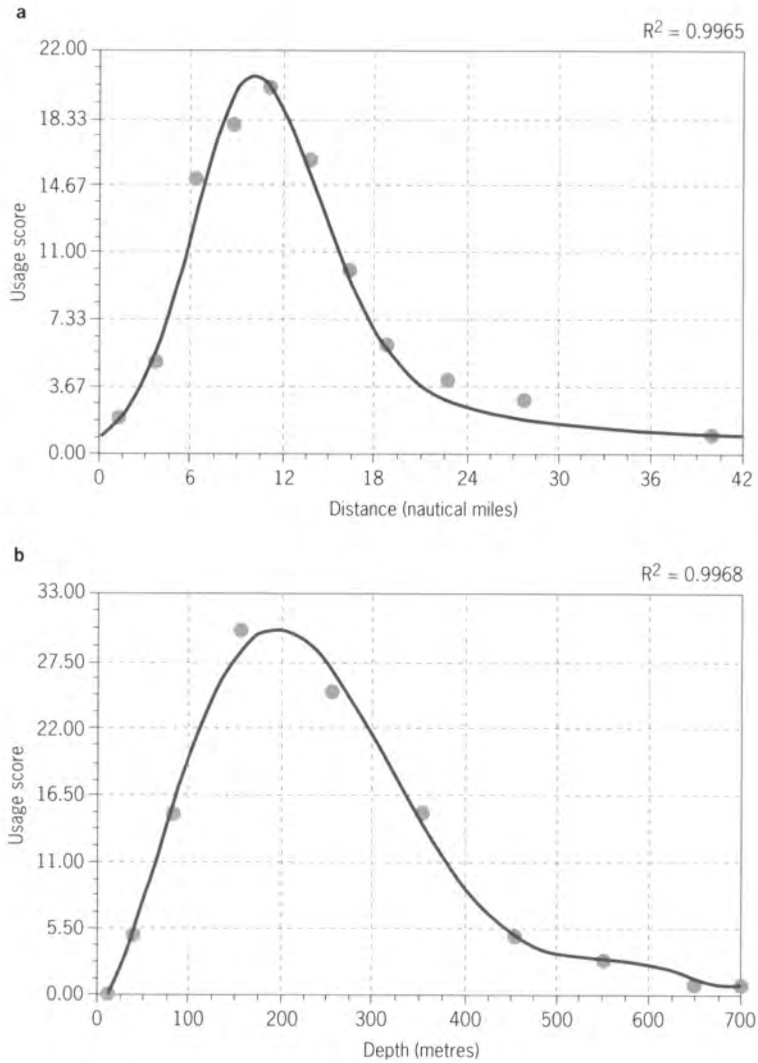


Figure 2
Functions used to model spatial distribution of fishing effort according to distance from the port (a) and depth (b). Points indicate estimated use by the fishing fleets (table 2).

Catch per unit effort

Catch per unit effort figures were derived from the yields of the three experimental trawl surveys.

A mean value of yield (kg) per hour for each overlapping haul was estimated. The mean yields per hour of the 130 hauls were then interpolated by means of universal kriging to derive a CPUE surface of the entire study area (Ardizzone & Corsi, 1997). Universal kriging assumes that spatial variation across the surface has a structural component (Cressie, 1993). This structural component (drift) is a systematic change in the values in a particular direction. The interpolation process can nevertheless estimate the structural effects and remove them from the original values.

Once the structural effects have been accounted for, the variable can be treated as a stationary regionalized variable. Regionalized variables have characteristics which are intermediate between random and deterministic variables and their rate of change in space can be described mathematically with a semivariogram. Based on the function used to fit the experimental semivariogram, if the regionalized variable can be assumed to be stationary, the kriging process can assign the best weight to all the sample points used in the interpolation.
For this paper we used universal kriging with a linear drift. To achieve higher accuracy kriging was performed separately in two sub-areas (North and South of Elba Island).

Surplus Production Model

To use the estimated CPUE and fishing effort with a Surplus Production Model (Schaefer, 1954) at any single pixel location, the first problem was to check if the data could fit the model at a very coarse scale. The Schaefer's model was thus fitted to the mean values of CPUE and of fishing effort by fishing zone. This process yielded an estimate of the angular coefficient (b) of the linear regression which was latter used in the analysis of the finer scale data.
The CPUE and effort pairs of each pixel of the study area were used to generate a scatter plot with fishing effort on the X axis and CPUE on the Y axis.
Assuming that at different stock densities the Schaefer's model would exhibit the same behaviour, a series of lines parallel to the above Schaefer's model were generated to partition the scatter plot into areas of homogeneous stock densities (fig. 3a).
The pixels belonging to different densities areas were then plotted in different shades on a map to show their spatial distribution.
Based on the same assumption of validity of the model at different densities, E_{MSY} and $CPUE_{MSY}$ were calculated for each of the homogeneous areas.
Finally the attractor function

$$CPUE = -b * E \qquad [1]$$

of the MSY parameters was used to divide the scatter plot into two areas (fig. 3b): one, which is under-exploited, lying above the line and one, which is over-exploited, below the line. Again the pixels were plotted on the map with different colours according to their state of exploitation to show their spatial distribution.
It can easily be shown that equation [1] represents the attractor function of the MSY points by taking into account that, for each of the model lines drawn on the plot, the equation, according to the Schaefer's model would be:

$$CPUE = a_i + b * E$$

with i varying from 1 to the number of lines. For these same lines, the effort corresponding to the MSY is given by:

$$E_{MSY} = -0.5 * a_i/b$$

and the CPUE corresponding to the MSY is

$$CPUE_{MSY} = 0.5 * a_i$$

Assuming an infinite number of parallel lines which divide the scatter plot, all the MSY points would line up forming a line whose equation is given by [1]. Thus pixels falling under the line defined by equation [1] represent areas in which the resource is over-exploited according to the Schaefer's model.

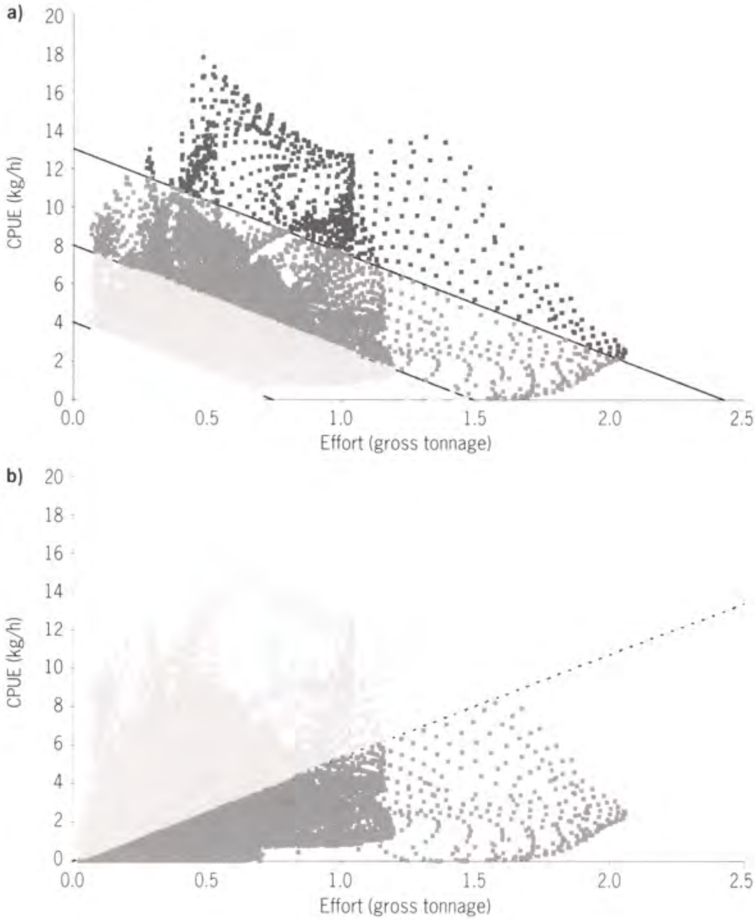
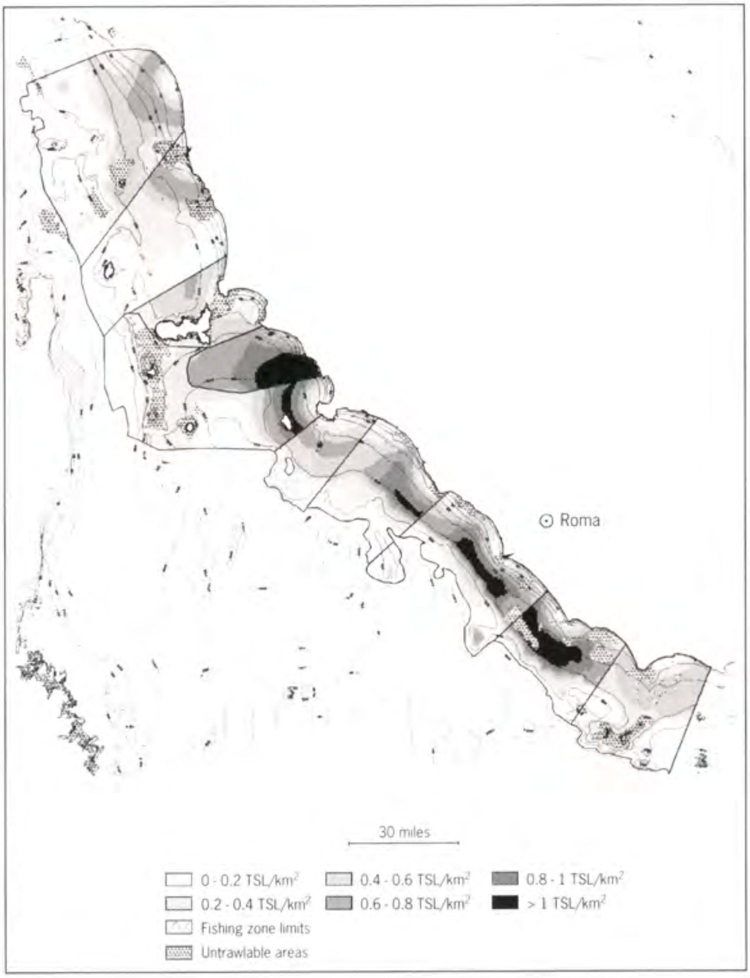


Figure 3
Scatter plot of estimated fishing effort and CPUE at each pixel: a) solid lines indicate the parallel lines used to partition the study area into homogeneous stock density areas; b) dashed line indicates the attractor function of MSY. Points above the dashed line are in a state of under-exploitation while those below the line are over-exploited.

Results

The functions illustrating the percentage of use of space with distance and depth (fig. 2), as derived from the data shown in table 2, produced the map of the distribution of the fishing effort for the entire study area (fig. 4). Areas of high concentration of fishing effort can be seen in the zones of Anzio, Fiumicino, Castiglione della Pescaia and Porto Santo Stefano. The CPUE surface (fig. 5) is similar to the distribution obtained with the national trawling survey data of the years 1985-1987 (Ardizzone & Corsi, 1997).

Figure 4
Estimated distribution of fishing effort (E).



Applying the general Schaefer's model to the mean values per fishing zone gives the general trend of CPUE and fishing effort (fig. 6). According to the model, the relationship between the two variables is rather good ($R^2 = 0.645$).

The scatter plot of CPUE *vs.* fishing effort for the 1x1 km pixels for the entire study area (fig 3a, b) shows a nearly right-triangular distribution with the catheta parallel to the two axes, and the hypotenuse roughly parallel to that of Schaefer's model obtained for the average data of the ten fishing zones. This similarity was used as the general basis for the applicability of the model to the pixel level and in particular of the angular coefficient ($b = -5.357$) of the straight line obtained from the ten fishing zones model.

Figure 5
Catch per unit effort (kg/h) surface of *Merluccius merluccius* from MEDITS trawl surveys, estimated by universal kriging.

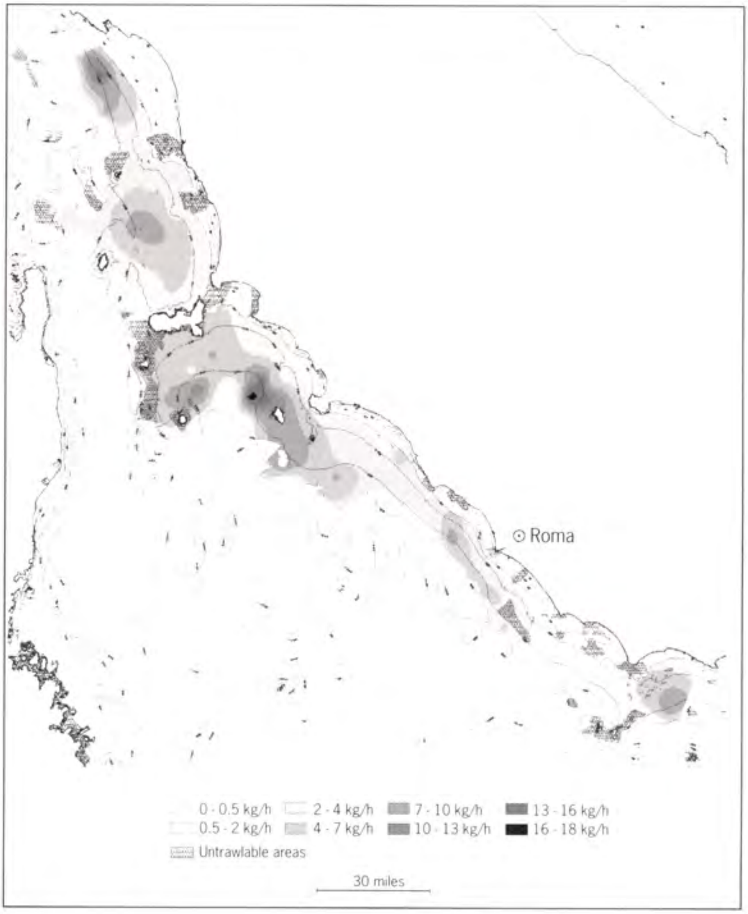
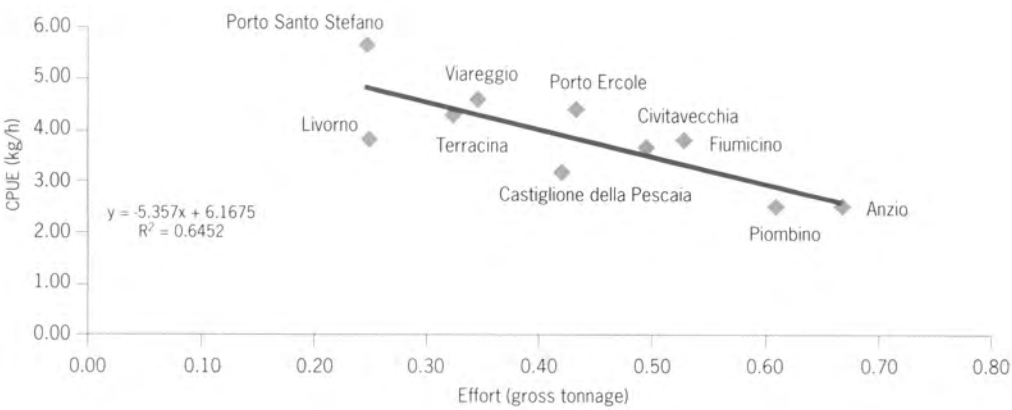
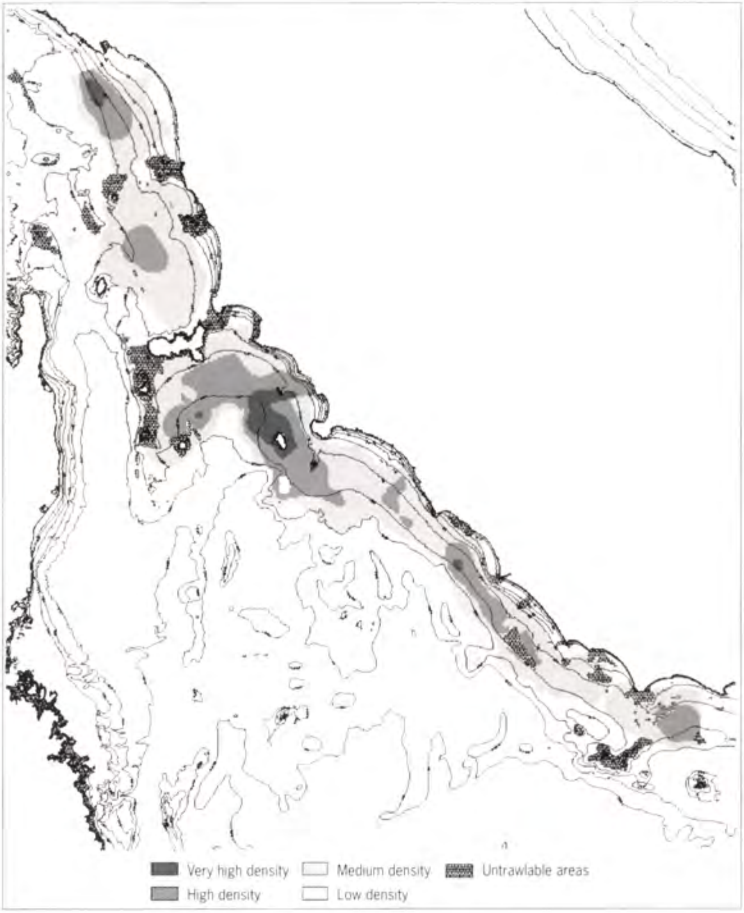


Figure 6
Schaefer Surplus Production Model for the mean values of CPUE and effort in the ten fishing areas.



The map (fig. 7) resulting from the partitioning of the scatter plot (fig. 3a) with the three parallel lines (a = 4, 8, 13) has a clear biological meaning, in that it reveals the marginal zones of the depth distribution of the hake (0-50 m and more than 500 m) with low density, and a central area with depths ranging from 50 m to 500 m having middle densities with some large zones at higher density. Thus, the spatial distribution of CPUE and E obtained appears to be coherent to the species' biological depth density scheme.

Figure 7
Areas of homogeneous stock density of hake according to the model.



The biological interpretation of the spatial distribution of the homogeneous density areas supports the following analysis of the results. According to equation [1], and using the b coefficient obtained from the Schaefer's model, each pixel has been classified according to its position in the scatter plot in respect to the line defined by equation [1] (fig. 3b). The spatial distribution of this partitioning (fig. 8) shows large zones of the southern study area and smaller ones in the middle and northern parts which appear over-exploited in accordance with the observed situation of CPUE (fig. 5) and fishing effort (fig. 4). It is

Figure 8
Spatial distribution of over-exploited areas.

important to note that the broader over-exploited areas along the coast and at higher depths should be interpreted with caution as they fall within the areas where the stock density is lower and are possibly the outcome of an interpolation artefact.

Discussion

The rationale behind this exercise can be summarized as follows: given a fishing ground in which the stock occurs at different densities, if we can estimate the CPUE achievable and the fishing effort applied, then the CPUEs of the entire fishing ground can be plotted against the fishing efforts to produce a scatter plot. If we assume the fishery to be in equilibrium, the scatter plot should look like a right triangle with each of the two catheta aligned to the axes of the plot. What we expect is that, at any given density (and any given set of homogeneous ecological conditions), the stock will respond to fishing effort following a specific Surplus Production Model. Areas of equal stock density and similar ecological features will yield lower CPUE if exploited with higher effort than if exploited with lower effort.

The biological meaning of such a model will tend to decrease in the very low density distribution areas, as it will for the marginal zones of the species' depth distribution (0-50 m and more than 500 m). Thus, these depth zones should not be considered in the final map.

The results of the model and therefore the behaviour of Surplus Production Models in conditions of varying stock densities seem to be coherent, nevertheless a few comments are in order.

Starting from the data layers used in the analysis, it is important to stress the simplistic approach used to extrapolate the spatial distribution of the fishing effort throughout the entire study area. Indeed, this part of the model is essentially based on a deductive approach in which subjectivity is very high. Nevertheless, the depth and distance ranges seem adequate in light of the general knowledge available on the use of space by the fishing fleets in the study area; the map of the fishing effort obtained from the combination of the two parameters used in our model seems equally adequate. Certainly, a better understanding of the parameters that drive the spatial distribution of the effort within a fishing ground is desirable, and some further investigation is obviously needed in this direction both to define possible new models and to set up procedures and sampling schemes capable of validating these models and possibly providing a means to measure their accuracy. Thus, it should be kept in mind that these functions are purely theoretical and functional to testing our hypothesis of modelling fishing effort and CPUE in conditions of variable stock densities.

Some caution should also be suggested in the use of the CPUE figures derived from geostatistical interpolation of the average of three years' data from experimental trawl surveys. In fact, this represents a coarsening of the time scale at which the model has been applied. Nevertheless, considering that the spatial distribution of CPUE is the result of both deterministic and stochastic events, and that in a process of modelling a distribution, stochastic events are regarded as disturbances caused by unpredictable or unaccountable events (Stoms *et al.*, 1992), averaging over a wider temporal range minimises the error related to the unaccounted stochasticity (Corsi *et al.*, in press), in this case for instance, local density variation caused by daily movements of the stock.

Another important consideration concerns the assumptions made to define the density partitioning model (fig. 3). The fact that the lines used are all parallel to one another is an over-simplification. In fact, there is no evidence that the same angular coefficient of the Schaefer's model applies to different stock densities. Nevertheless, for the sake of simplicity in the above application, we assumed that the lines are parallel to each other so that a single production model estimated as mean values of the different areas applies to different densities. Again we cannot provide any specific evidence that the model that applies to the mean values of the different fishing areas can also represent the CPUE *vs.* fishing effort relationship when a finer spatial distribution of the two parameters is considered. Furthermore, this model lacks a way of defining its accuracy and thus of validating its results.

A direct consequence of the last consideration is that the attractor function [1] only holds true if the parallel partitioning of the scatter plot holds true. Conversely, more complex curves would describe the function which divides the scatter plot into an over-exploited and an under-exploited sections.

Conclusions

Although with the caution outlined in the discussion, the model presented can open new approaches in stock assessment.
Both geographic results seem promising. The spatial distribution of ecological homogeneous areas has the potential to introduce new ideas to support research (*e.g.* different stratification criteria for research surveys, correction factor to be applied to abundance indices derived from experimental surveys CPUE); while the detailed distribution of the exploitation status of the stock will probably enable more precise management actions. To this extent it should be noted an increasing concern of the environmental conservation arena towards fisheries exploitation policy and resources conservation. This concern will certainly drive decision making in the next future and will increase the demand for more adequate and more precisely located decision support tools, such as the one presented.

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Trawl survey forecasting

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Abstract

Previous contributions concerning the need for a methodological change in the use of trawl survey information in an assessment/management framework are briefly reviewed. A heuristic method is proposed involving the use of frontier achievements of parallel computation that provide for an approach to human intuition: Artificial Neural Networks (ANN). This in turn allows a methodological switch from a single stock to a multispecies approach. The method was validated by checking the forecasting performance for catch rates obtained from field data collected by trawl surveys in a given study area (the Sicilian Channel within the mid-line).

Wise men what is approaching

Gods perceive the future,
men the present
wise men
what is approaching

(Filostratos, Apollonio's of Tiana life, VIII, 7).

Introduction

This paper relates to previous attempts in fisheries science at meeting the demands of a changing industry (Levi, 1978, 1984; Levi & Andreoli, 1989) and results from the convergence of two different research pathways. One pathway concerns the Italian proverb "fare di necessità virtù" (make a virtue of necessity), which has been referred to elsewhere as the difference between "l'arte di arrangiarsi" (the art of managing) and the struggle for management (Levi, 1994). For the time being, this amounts to admitting the following points in the typical Mediterranean situation:

- that the database on which stock assessment is traditionally based (*i.e.* commercial catch/effort and length/age data) is not reliable;

- that new methods (and materials) must be devised or traditional ones adapted by the "art of managing", which will be timely enough to help management.
The second pathway begins with the consciousness that dissatisfaction with the current methodological approach is now widespread and profound (Caddy, 1998) *i.e.* the notion that several population dynamics models are needed to respond to or stimulate the demand for fishery resources' management. According to the most customary approach to understanding the exploitation state, past history is reconstructed and, on the basis of some hypothesis about boundary conditions, possible scenarios are developed that depend on the modification of the variables under administrative control (Beverton & Holt, 1957; Gulland, 1969; Pope, 1979). Without unnecessary rehashing of these matters or reconstruction of well-known debates, reference will be made to personal contributions on the subject, which have tried to identify the causes of dissatisfaction (Levi & Andreoli, 1995, 1998) and to the literature mentioned therein as well as to some recent significant contributions (Ludwig *et al.*, 1993; Aron *et al.*, 1993; Rosenberg *et al.*, 1993; Gauldie, 1995; Stephenson & Lane, 1995; Spurgeon, 1997) also indicative of the above-mentioned apprehension.
This work is a first attempt to overcome this unsatisfactory situation, and it is hoped that future developments will be of greater benefit than a specific case study. Basically, "the model" employed here, which attempts to make predictions about the apparent and relative abundances of fish resources, is based on an intuition not new to scientific literature and surely present in the unconscious of the scientists concerned. It assumes that the fluctuations in the above-mentioned abundances are determined, in variable proportions, by the complex (often non-linear) relations of the considered resources with other biological resources co-occurring in the ecosystem and with significant environmental variables (among which catch activity or disturbance by fishing activity can sometimes be included).
This model assumes that this is true (to a different extent and variable in time and space) for the overwhelming majority of resources caught during trawl surveys. Therefore, if at the same time the fluctuations of target resources and of all others (target and non-target) are considered, there is in fact an implicit examination of the actions and interactions of these concomitant causes of fluctuations.
The first attempts to test our assumptions were made using current statistical techniques (*e.g.* multiple non-linear regression), even though the results were very poor and contradictory or completely unsatisfactory. More customary forecasting methods commonly used in different scientific fields, such as ARIMA and transfer function models (Makridakis *et al.*, 1983), were discarded in view of their inability to capture the covariance of so many factors and because of the small number of points in the series.

Another set of methods of increasing importance in recent years was then resorted to, *i.e.* those that use parallel calculus on large systems or its simulation on personal computers. This approach is now employed everyday in many areas, including image processing, financial forecasting, machine control and optimization: Artificial Neural Networks (ANN) (Dayhoff, 1990; Von der Malsburg *et al.*, 1996; Rojas, 1996; Schiavo, 1996). Other applications to fish and fisheries data are on record (Jarre-Teichmann *et al.*, 1995; Aoki & Komatsu, 1997), but to our knowledge differ from the one proposed here.

A review of the state of the art of neural nets and their application can also be found on an Internet News server (Sarle: *"Comp.ai.neural-nets FAQ"*).

An attempt will be made here to avoid technicalities as much as possible in order to limit the difficulties that fisheries biologists may run into if they approach the method from traditional models of population dynamics. For us, these difficulties have been overcome mainly by chance and necessity since one of the co-authors has been acquiring know-how for some years on the development of neural nets (Gioiello *et al.*, 1995) and their application to interesting cases for fish studies at the Institute of Mazara (Jereb *et al.*, 1996).

However, to reduce these difficulties even further, it should be recalled that all models are explicative to the extent that the very big choice of the variables to be considered in input (and what is expected as output) inevitably presupposes an explicative hypothesis (Popper, 1970; Hannon & Ruth, 1994). This also applies to ANN.

Though relations among variables are analytically examined and made explicit, and the achievement of results in output is connected with more or less certainty to those relations, nothing changes from the viewpoint of the explicative value of the model: what really counts is the fitting of the expected result to the measured data. Moreover, the notion that relationships between ANN and statistical models can be demonstrated (Sarle, 1994) is also helpful.

Materials

Data used as input to ANN are hourly catch rates in weight and in numbers per georeferenced haul obtained within the framework of the EU-DG XIV MEDITS Programme of trawl surveys from 1994 to 1997. All participants in MEDITS used the same gear and survey design. Details are available in the program literature (Anon, 1998; Bertrand *et al.*, 2000).

Our study area is depicted in figure 1, and some major operational data are summarized in table 1. What needs to be emphasized mainly is the strong attempt to keep experimental conditions as constant as possible from year to year (the same R/V, gear, crew, season, daytime operations, location of hauls and sampling design).

Figure 1
The study area:
A = presently surveyed area;
B = Sought future area to be surveyed;
C = North African countries' territorial waters.

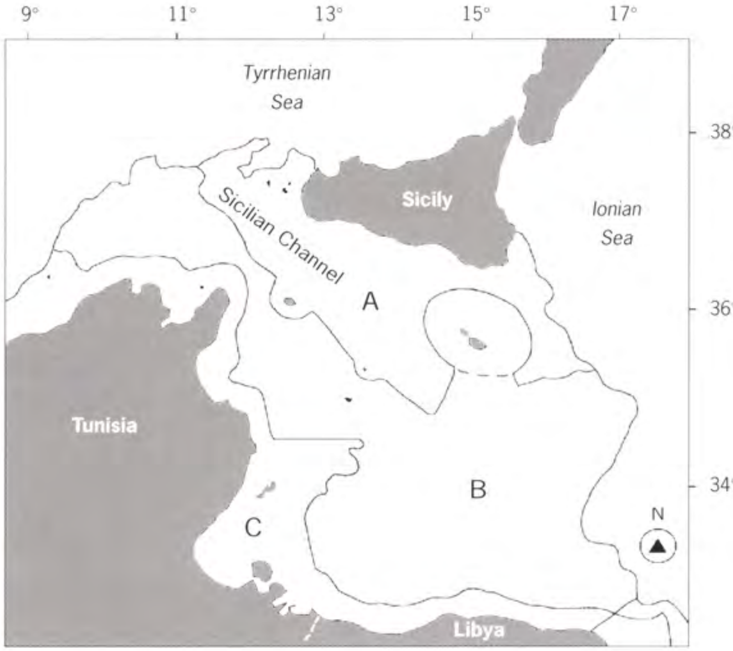

Table 1 - Some major informations on MEDITS trawl surveys in the Sicilian Channel.

				Stratum area (km²)				
				3145	6610	9866	13424	15653
Year	Time	Total number of hauls		Stratum depth (m)				
				10-50	50-100	100-200	200-500	500-800
94	June 2-June 28	56	Nb hauls	4	8	10	15	19
95	June 3-June 17	56	Nb hauls	4	8	10	15	19
96	May 31-June 12	56	Nb hauls	4	8	10	15	19
97	June 3-June 14	56	Nb hauls	4	8	10	15	19

Conversely, the political constraint limiting the study area to within the mid-line between Italy and Tunisia may have prevented full coverage of some of the stock distribution area.

Six main species were selected among the "target species" of MEDITS for this first experiment: *Aristaeomorpha foliacea*, *Illex coindetii*, *Loligo vulgaris*, *Merluccius merluccius*, *Mullus barbatus* and *Parapenaeus longirostris*. They were correlated with another 183 species.

The input information was thus a matrix made up of 56 vectors of 378 real numbers, *i.e.* 189 pairs of columns (number of individuals and weight in kilogramme per haul) corresponding to as many species (table 2) for each haul. Each of the 56 hauls was identified by geographic co-ordinates and depth at the start of trawling operations.

Table 2 - List of the 189 species considered in input. The six chosen to try forecast in output are in bolds.

Abralia veranyi, Acantholabrus palloni, Alepocephalus rostratus, Alloteuthis media, Alloteuthis subulata, Alpheus glaber, Anthias anthias, Aphia minuta, Argentina sphyraena, Argyropelecus hemigymnus, ***Aristaeomorpha foliacea,*** *Aristeus antennatus, Arnoglossus imperialis, Arnoglossus laterna, Arnoglossus rueppelli, Arnoglossus thori, Aspitrigla cuculus, Aspitrigla obscura, Aulopus filamentosus, Bathypolypus sponsalis, Blennius ocellaris, Boops boops, Calappa granulata, Callanthias ruber, Callionymus lyra, Callionymus maculatus, Synchiropus (Callionymus) phaeton, Capros aper, Centracanthus cirrus, Centrolophus niger, Centrophorus granulosus, Centrophorus uyato, Dactylopterus (Cephalacanthus) volitans, Cepola rubescens (macrophthalma), Chauliodus sloani, Chimaera monstrosa, Chlorotocus crassicornis, Chromis chromis, Citharus linguatula (macrolepidotus), Chlorophthalmus agassizii, Coelorhynchus coelorhynchus, Conger conger, Dalophis imberbis, Dentex macrophthalmus, Diplodus annularis, Dorippe lanata, Echelus myrus, Eledone cirrhosa, Eledone moschata, Engraulis encrasicolus, Epigonus denticulatus, Epigonus telescopus, Etmopterus spinax, Eutrigla gurnardus, Gadiculus argenteus, Gaidropsarus mediterraneus, Galeus melastomus, Geryon longipes, Glossanodon leioglossus, Gnathophis mystax, Gobius niger jozo, Goneplax rhomboïdes, Helicolenus dactylopterus, Heptranchias perlo, Hexanchus griseus, Histioteuthis bonnellii, Histioteuthis reversa, Homola barbata, Hoplostethus mediterraneus, Hymenocephalus italicus,* ***Illex coindetii,*** *Lampanyctus crocodilus, Lepidopus caudatus, Lepidorhombus boscii, Lepidorhombus whiffiagonis, Lepidotrigla cavillone, Lepidotrigla dieuzeidei, Liza aurata, Loligo forbesi,* ***Loligo vulgaris,*** *Lophius budegassa, Lophius piscatorius, Macroramphosus gracilis, Macrorhamphosus scolopax, Maja squinado, Liocarcinus (Macropipus) depurator,* ***Merluccius merluccius,*** *Micromesistius poutassou, Microchirus variegatus, Molva dipterygia macrophtalma, Molva molva, Monochirus hispidus, Mora moro,* ***Mullus barbatus,*** *Mullus surmuletus, Munida intermedia, Mustelus mustelus, Myctophidae, Nemichthys scolopaceus, Neorossia caroli, Nephrops norvegicus, Nettastoma melanurum, Nezumia aequalis, Nezumia sclerorhynchus, Notacanthus bonapartei, Octopus salutii, Pteroctopus tetracirrhus, Octopus vulgaris, Oxynotus centrina, Pagellus acarne, Pagellus bogaraveo, Pagellus erythrinus, Palinurus elephas,* ***Parapenaeus longirostris,*** *Paromola cuvieri, Parthenope macrochelos, Pasiphaea multidentata, Pasiphaea sivado, Peristedion cataphractum, Phycis blennoides, Phycis phycis, Pisa armata, Plesionika gigliolii, Plesionika heterocarpus, Plesionika martia, Polycheles typhlops, Pomatomus saltator, Raja alba, Raja asterias, Raja clavata, Raja melitensis, Raja miraletus, Raja montagui, Raja oxyrinchus, Raja radula, Rissoides pallidus, Rossia macrosoma, Sardina pilchardus, Sardinella aurita, Scaeurgus unicirrhus, Scomber (Pneumatophorus) japonicus, Scomber scombrus, Scorpaena elongata, Scorpaena notata, Scorpaena porcus, Scorpaena scrofa, Dalatias (Scymnorhinus) licha, Scyliorhinus canicula, Scyliorhinus stellaris, Sepia elegans, Sepia officinalis, Sepia orbignyana, Sepiola* spp., *Serranus cabrilla, Serranus hepatus, Sergestes robustus, Solea variegata, Solea vulgaris, Solenocera membranacea, Pagrus (Sparus) pagrus, Sphoeroides cutaneus, Sphyraena sphyraena, Spicara flexuosa, Spicara maena, Spicara smaris, Sprattus sprattus, Squalus acanthias, Squalus* *blainvillei, Squilla mantis, Stomias boa, Symphurus nigrescens, Synodus saurus, Syngnathus acus, Todarodes sagittatus, Todaropsis eblanae, Torpedo marmorata, Torpedo nobiliana, Trachurus mediterraneus, Trachurus picturatus, Trachurus trachurus, Trachinus araneus, Trachinus draco, Trigla lucerna, Trigla lyra, Trigloporus lastoviza, Trisopterus minutus capelanus, Uranoscopus scaber, Xiphias gladius, Zeus faber*

The training file had one additional column, the 379th, indicating the hourly catch rate in weight of the considered target species obtained the following year in the location geographically closest to the current year's haul site. The input matrix was normalized between 0 and 1, whereas output values were normalized between 0.1 and 0.9.

Methods

ANN are parallel computational structures of highly interconnected simple processors called neurons, which simulate to some extent the structure and functioning of the brain (McClelland & Rumelhart, 1987). Neurons can be arranged in a single layer or in two or more layers. In the latter case, one layer (the so-called input layer) is indirectly connected through previous layer(s) outputs: neurons of the last (output) layer produce the final response. The weight or strength of neuron connection is fundamental to ANN performance and needs to be achieved to relate inputs properly to desired outputs. This process, known as ANN training, can be performed both in an unsupervised and a supervised way. With supervised training, the net is given both the input and the desired output, and the supervisor, *i.e.* the neural algorithm, gradually modifies the connection weight, to reduce the difference between actual and desired output.

The main concept of ANN is to learn from experience, not from programming, by the creation of an internal representation of reality based on the "raw" information supplied (Lawrence, 1993). Their main interest from a scientific point of view lies in the possibility of building up systems able to perform successfully when highly complex tasks are dealt with and in which classical algorithmic approaches might not be entirely satisfactory.

ANNs are mainly employed for classification purposes, but can also be used for prediction purposes when historical series of data are provided (Dayhoff, 1990; Hertz *et al.*, 1991).

The main advantage of using ANNs for prediction is that no *a priori* assumptions about the relations between independent and dependent variables are needed. Also, "unlike splines and polynomials", they "are easy to extend to multiple inputs and outputs without an exponential increase of the number of parameters" (Sarle, 1994). The main disadvantage is that there is no way to express relations between input and output data in traditional mathematical terms, *i.e.* functions.

QwikNet was used for the present exercise (see Appendix).

According to available data, two different validation procedures can be used. Small amounts of data are better fed into the System as a whole, while larger sets can be split into two files with .TRN and .TST extensions (training and test files respectively).
The first case is called "cross-validation", the second "set-validation". During cross-validate training, the whole data set is automatically divided into two sets: 90% for training and 10% for testing. The testing set is not used to update the weights and can therefore be used as an indication of whether memorization is taking place or not. When a neural network memorizes training data, it produces acceptable results for these data, but poor results when tested on unseen data. Memorization can be detected by watching *via* the error plot window for an increase in testing error as compared to training error.
The parameters used in QwikNet are:
- the learning rate, η, that controls the rate at which the network learns (see back-propagation). In the usual circumstances, the network learns faster when the learning rate is higher. The valid range is between 0.0 and 100.0. A good initial guess is 0.1 when training a new network. If the learning rate is too high, the network may become unstable, in which case the weights should be randomized and training restarted. The RProp and Delta Bar Delta algorithms update this parameter adaptively;
- the momentum parameter, α, which controls the influence of the last weight change on the current weight update (see back-propagation). The valid range is 0.0 to 1.0. Momentum usually results in faster learning, but can cause instability in some cases if set too large;
- the convergence-tolerance parameter, which specifies the stopping criterion for the RMS training error. Training will stop when the total RMS training error falls below this value;
- maximum # epochs, which control the maximum number of epochs to be used for training. One epoch is equivalent to one complete sweep of the training data set through the network;
- error margin, which is used by the network to classify the number and percent of training patterns the network has learned. Any pattern with a total RMS training error less than this value is considered as learned. The number and percentage of learned patterns are shown in the Training Info section of the main window;
- pattern clipping specifies the degree to which patterns that have been learned participate in future learning. A pattern is considered as learned when its error is less than the value specified in the Error Margin field. The Learning Rate, η, is multiplied by this value for every pattern that has been learned. If this parameter is less than 1.0, the effect of previously learned patterns on future learning is reduced, thus emphasizing learning on patterns with large errors. The valid range is from 0.0 to 1.0. This option is useful when it is desirable to reduce the maximum

error in the training set. Setting this parameter to 1.0 removes the effect of this option, and setting it to 0.0 provides training exclusively on patterns with errors above the error margin;
- number of hidden layers, which specifies the total number of hidden layers in the network. The valid range is from zero to five. The size and activation function for each hidden layer is set in the Network Topology section;
- input noise, which specifies the amount of Gaussian noise to be added to the input training patterns. Training with a small amount of noise (sometimes called jitter) helps prevent overfitting and usually improves generalization;
- weight decay, which specifies the amount of weight decay in the training algorithm. Weight decay tends to decrease large weights in the network and usually improves generalization.

In our simulations, the following parameters were used:
- the learning rate, $\eta = 0.1$;
- the momentum parameter, $\alpha = 0$;
- the convergence-tolerance parameter = 1e-5;
- maximum # epochs = 10,000;
- error margin = 1e-5;
- pattern clipping = 1;
- number of hidden layers: 1, with 25 neurons activated from sigmoid function;
- input noise = 0;
- weight decay = 0;
- training algorithm: QuickProp;
- weights: max 10, min -10;
- weight perturbation = 20%;
- neuron saturation threshold = 80%;
- hidden layer: 1 with 25 neurons;
- activation function: sigmoid
- cross-validate training.

Results

After training ANNs for two successive years, the pooled (across hauls) normalized catch rates predicted for the third year were plotted on the same graph with pooled (across hauls) normalized survey results for the same species (fig. 2). Two years (1996 and 1997) were thus predictable out of four (1994-1997) available. Normalization and pooling both of forecasts and real data should make comparison of system performance easier.

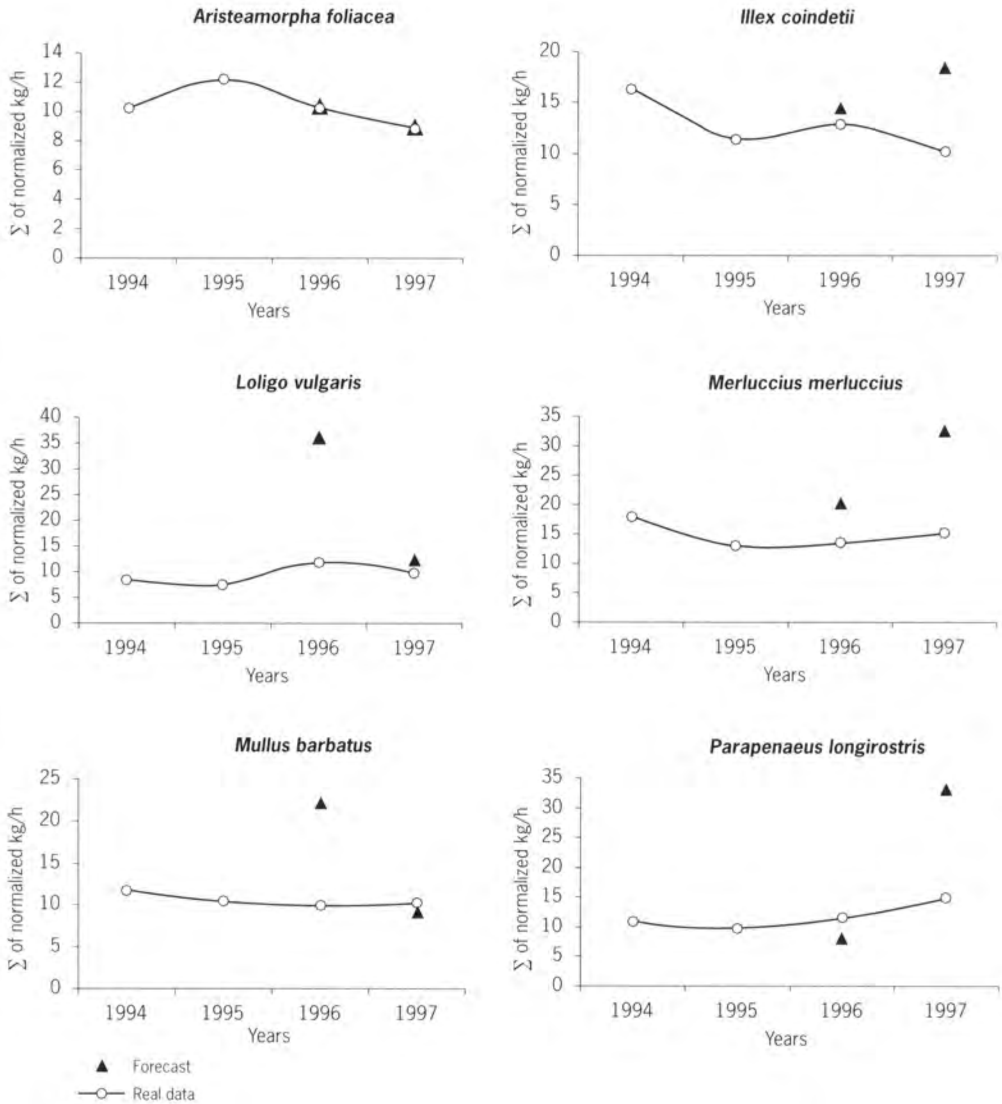

Figure 2 - Forecasting performance of the Neural Net on six target species.

Discussion

For the sake of the present very preliminary exercise, priority was given to "short training" (which is generally imposed by the real situation in the Mediterranean) rather than "prolonged learning" of the system (which is possible when long historical series of data are available).

Hence, no improvement of the system with time is to be expected, and convergence or divergence of fitting must not be interpreted in terms of improvement or worsening. The reader can easily appreciate how forecasting seems to be more credible (*i.e.* closer to experimental results) for some species than others.
However, it would seem advisable not to interpret the results in biological terms. One thing can be said at this stage, both on the basis of the nature of the method itself and of the enclosed graphs: forecasting performance for one species is rather independent of the contrast in input data for the same species. Yet the inner variability of each pooled value must still be analyzed.
Similarly, there is a major caveat: no generalizations should be tried at this stage. Instead, a long, wide and serious verification of the method needs to be carried out on the same and many other data sets before the proposed method(s) is(are) validated.
Before considering how to improve forecasts further (which in our opinion is possible), it should be determined how the results can be used, since the programme that supplied the data (MEDITS) is probably intended sooner or later to produce management indications.
The EU management measures for demersal fisheries currently in force in the Mediterranean are based on technical regulations concerning the gear (*i.e.* building characteristics and usage methods) (Anon., 1994) and rough measures of fishing power reduction by countries (Anon., 1997).
Unfortunately, there are serious deficiencies in monitoring both kinds of measures, although possible solutions have been given from time to time, (*e.g.* Mortera & Levi, 1981; Bazigos *et al.*, 1984; Cingolani *et al.*, 1986; Levi, 1991; Andreoli *et al.*, 1995a, 1995b, 1996). In general, however, it can be said that demersal fisheries, under the present conditions in the Mediterranean and according to the ICES' North-European standard, are not managed. Serious revisions of such an over-simplified vision[1] (Salz, 1997) are under way, as well as serious self-criticisms on the effectiveness of the assessments carried out at the ICES (Holden, 1994) and in the North-Atlantic (Kulka *et al.*, 1995; Myers & Cadigan, 1995; Bowering *et al.*, 1997), in the light of the constant difficulty in implementing management decisions and of the unexpected collapse of some resources.
If this is how things stand, what is the use of predicting apparent and relative abundances one or two years in advance and in a spatially

1. "Marine refugia" (periods/areas closed to trawling) also seem to be promising measures. The gratifying results obtained some time ago in Castellon (Suau, 1979) in Spain and the unexpected effects of the experience in Cyprus (Garcia & Demetropoulos, 1986) and most recently in Castellammare del Golfo (Pipitone, 1995) suggest not only that the setting up of similar experiences should be taken seriously into consideration, but also that present population dynamics tools do not seem to account for the behaviour of a multi-species system when a control variable (*i.e.* fishing effort) is cut out completely.

aggregated format, as in this (our first experiment) or in some spatially disaggregated geographical representation (Garcia, 1993; Meaden & Do Chi, 1996)? Let us try to give a first brief answer.

If State and EU interventions continue to be similar to those in the past, it may be useful for decision-makers to know biomass indices (and hopefully length/age structures in the future) of fish populations in advance, before encouraging or discouraging the industry.

If public interventions were limited instead to handling fishing licenses, enforcing the rules of competition and taxing profits (what is sometimes called "co-management"), it would probably be the professional categories which would be interested because of their cost/earning projection needs (Keen, 1990).

Apart from our first and very preliminary attempt, whose value may mainly consist in the possibility of making early predictions based only on a few years of available data (Gulland, 1988a, 1988b), which are relatively cheap to collect, the predictions are surely capable of improvement. First, a longer time series should be used that would also allow comparing ANNs with other common forecasting methods.

The present low reliability beyond one year might suggest, among several possible explanations, an insufficient coverage of the distribution area of some species (Levi, 1993) and/or an insufficient sampling intensity: hypothesis testing is already possible, and we are planning to include it within our programs in the near future.

It is also foreseen in our program to take other variables into consideration that were not explicitly included in our first attempt, though just as constant "boundary conditions": fishing power and other "environmental" variables of the ecosystem. This could be done by using available measures and through sensitivity analysis.

It is assumed that boundary conditions, mainly fishing effort, remained stable or varied in the last few years just as much as during the period of time between reference and training years. That seems reasonably acceptable, considering the situation in the area. More generally though, if there are reasons to suspect that this does not apply to some variables (measured ones), then they should become explicitly input variables.

In other words, we intend to test the assumption that such variables are entirely mirrored by globally considered fluctuations of fish resources within the ecosystem.

Conclusion

This contribution is a further step in a journey begun in 1979, marking the heuristic potential of trawl surveys (Levi & Andreoli, 1979), which was carried on in 1982 by giving them priority in the study for the first application of the fishing planning law in Italy (Levi & Spagnolo, 1982) and then in 1994 with a "template paper" showing the possibility of using trawl surveys to do single-species stock assessment (Levi *et al.*, 1993). The present step is an attempt to escape from the paradigm of a single-species approach.

Appendix

QwikNet (Artificial Neural Network for Windows) is a shareware program developed in the USA by Craig Jensen (*cjensen@kagi.com*). The last version, QwikNet32 v2.10, was released in July 1997. It is a powerful, yet easy-to-use Artificial Neural Network (ANN) simulator that implements several powerful methods to train and test a standard feed-forward neural network in an easy-to-use graphic environment. However, it is at the same time simple enough for beginners to use.

QwikNet offers a wide array of features that make designing, training and testing neural networks easy and fun.

The neural network implemented in QwikNet is called a "feed-forward multi-layer perceptron", which simply means that it is made up of several layers and that the data propagate forward through the network from input to output.

The main design features of QwikNet are:

- up to five hidden layers;
- an unlimited number of neurons in each layer;
- automatic data-scaling;
- unlimited training data file sizes;
- on-line help always available.

It also offers these simple training features:

- the choice of several advanced training algorithms;
- automatic prevention of neuron saturation;
- cross-validation training;
- visual monitoring of the learning process and network weights;
- input noise and weight decay.

During testing, at least, it also offers these features:

- a graphic view of network outputs and errors for both training and testing data files;
- the creation of three-dimensional contour plots;
- error histogram plots showing the distribution of errors;
- the possibility of creating and updating all plots during training;
- screen shots;
- a QwikNet main interface;
- on-line training plots;
- three-dimensional contour plots;
- error analysis plots;
- a choice of sigmoid, tanh, Gaussian, or linear activation functions.

The training method specifies the algorithm used to train the neural network. In some cases, the choice of training method can have a substantial effect on the speed and accuracy of training. The best choice depends on the problem, and trial-and-error is usually needed to determine the best method.

QwikNet offers these training methods:

• Back-Propagation Online: back-propagation is the most commonly used training algorithm for neural networks. It updates after the weights of each pattern are presented to the network;

• Randomized Patterns: online back-propagation in which the order of the input patterns is randomized prior to each epoch. This makes the learning process stochastic, which is preferable in most cases;
• Back-Propagation Batch: back-propagation with weight updates occurring after each epoch;
• Delta Bar Delta: an adaptive learning rate method in which every weight has its own learning rate;
• RProp (*i.e.* resilient propagation): an adaptive learning rate method in which weight updates are based only on the sign of the local gradients, not on their magnitudes;
• QuickProp: a training method based on the following assumptions:
- error $E(w)$ for each weight can be approximated by a parabola that opens upward;
- the change in slope of error $E(w)$ for this weight is not affected by all other weights that change at the same time.

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Chapter III

Biological parameters

Contribution to the knowledge of *Citharus linguatula* (Linnaeus, 1758) (Osteicthyes: Heterosomata) in the Iberian Mediterranean

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Abstract

The spotted flounder *C. linguatula*, a benthic species widely distributed throughout the Mediterranean and the western Atlantic, is caught as an accompanying species by trawling fleets. The present study, conducted in accordance with the objectives of MEDITS international trawling cruises, studied the biology and distribution of this species with data obtained during annual cruises from 1994 to 1997. The species has a very wide distribution, and the proportion of larger sizes increases with depth. The following size-weight relationship is proposed for all individuals: weight (g) = 0.00604 * size (cm) $^{3.047}$. A sexual dimorphism was apparent in sizes. The size for which gonads start to differentiate is around ten or eleven centimetres. Estimations of the Von Bertalanffy parameters were performed, and the expression $L_t = 33.5 * (1 - e^{-0.28 * (t - 0.09)})$ was obtained for the total population.

Introduction

The Genus *Citharus* Röse, 1793, is represented by a single species (*C. linguatula* Linnaeus, 1758) distributed in the Mediterranean as well as the eastern Atlantic (Portugal and Morocco) down to the coasts of Angola (Nielsen, 1986). It is found on the muddy bottoms of the continental shelf and shows some characteristics clearly defining it as benthic.

In the Spanish Mediterranean it is frequently trawl-fished. Although not particularly abundant, it is highly appreciated for its flesh (Planas & Vives, 1956) and is used to make up boxes of mixed fish in fish markets. In the Alborán Sea, the contribution year-round of young individuals (7-8 cm) is higher than that of adults (12-25 cm) (Gil de Sola, 1993). The fish are marketed under the names of "japonesa", "solleta" or "pelúa" according to the particular zones and landing ports.

This species has been studied in terms of its biology and reproduction (Planas *et al.*, 1955; Planas & Vives, 1956) as well as its larval development (Sabatés, 1988) and growth (Vassilopoulou & Papaconstantinou, 1994). We considered that the biological and distributive aspects of this species made it suitable for inclusion within MEDITS international fishery survey cruises, and that this would provide a useful means of obtaining further data.

Materials and methods

This study was based on bottom trawls carried out by the R/V *Cornide de Saavedra* during cruises in May and June of 1994, 1995, 1996 and 1997, using experimental fishing gear (GOC 73) designed for MEDITS international trawling cruises within EU Project MED 93/018.
The area surveyed (Gibraltar to Cape Creus) and the depth ranges covered (five strata between 10 and 800 m: stratum A: 10-50 m, stratum B: 51-100 m, stratum C: 101-200 m, stratum D: 201-500 m, and stratum E: 501-800), were sampled by 30-min/haul on bottoms down to 200 m and 60-min/haul on bottoms below 200 metres.
The distribution of the number of hauls was more or less equilibrated between the different depth strata (about 20% of the total for each, except stratum A which made a 10% contribution). All the characteristics of each haul (situation, depth, course, etc.) were recorded, as well as those for any catch obtained (species, sizes, weights, etc.).

Samplings

Specifically in the case of the spotted flounder, biological sampling was performed on 850 individuals (46%) out of 1,845 specimens caught, for which total length (mm) and individual weight (g) were checked. In addition, sex determination and macroscopic studies of sexual maturity were carried out. Six different maturity states were established for males and females: virgin, developing, prespawning, spawning, post-spawning, resting.
Data were entered into a standard record indicating the main characteristics of the haul as well as the weight and total number of specimens for the species. The records were subsequently computerized to create a database for subsequent analysis.

Biometric relationships

Relationships between total length and total weight were determined by adjusting the data to a potential relationship in the form of $W = a * L^b$, where W is the weight in grammes, L the size in centimetres, a and b the parameters to be estimated (b being the coefficient of allometry). In addition, a significance test (Sokal & Rohlf, 1969) was carried out to determine whether the b coefficient was different from 3, and the level of significance was determined with a Student's *t*-test (*** < 0.001; ** < 0.01; * < 0.05 and ns < 0.1). These estimations were performed for the relationships of the various groups separately (males, females, and undefined) as well as for all fishes together. Differences in growth curve slopes were statistically tested (*t*-test, ANOVA, ANCOVA) using Systat 5.04 software.

Growth

A study of size frequencies was carried out to determine the size-age relationship (Petersen method), which allowed growth variations to be detected with time and expressed as a function corresponding to an asymptotic curve. Due to the type of sampling carried out, *i.e.* with a large geographic range and very localized in time, it was decided to group all individuals caught in each cruise into a single size frequency, on the assumption that this "synthetic cohort" accurately reflected the distinct cohorts belonging to various years.

The growth model adopted was that of Von Bertalanffy (VBGF), whose expression is $L_t = L_\infty (1 - e^{-k(t-t_0)})$, where L_∞ is the theoretical maximum size, L_t the size at age t, K the growth factor and t_0 the age at which the size is zero (a slightly negative or fully positive value close to zero). For the estimation of L_∞, K and t_0, the automatic calculation program FISAT was applied (Gayanillo *et al.*, 1994).

Length distributions were grouped in size classes of one centimetre, with a running mean of three consecutive classes, for the total number of individuals caught in each cruise. The "best combination" among the Von Bertalanffy growth parameters was estimated by applying the FISAT programme (ELEFAN I sub-program), with the criterion of optimizing the values of the "goodness index" (Rn). Bhattacharya modal breakdowns were carried out in a similar way (FISAT program, MPA sub-program).

Gonadal maturity

From the data on sex and maturity, the sex ratios (Prop. Sex = nb ♀ / nb ♂ + nb ♀) were determined, using a G-test for heterogeneity (Sokal & Rohlf, 1969) to determine whether the predominance of each sex in each size range was significant or not. No other analysis was carried out due to the small number of mature individuals caught.

Results

Citharus linguatula was found in 80 of the 405 hauls (20%) carried out during the cruises, constituting a total of 1,845 specimens and a total weight of 38,944 grammes. Forty-six per cent of these specimens were used for biological sampling (850 individuals and a total weight of 25,313 g).

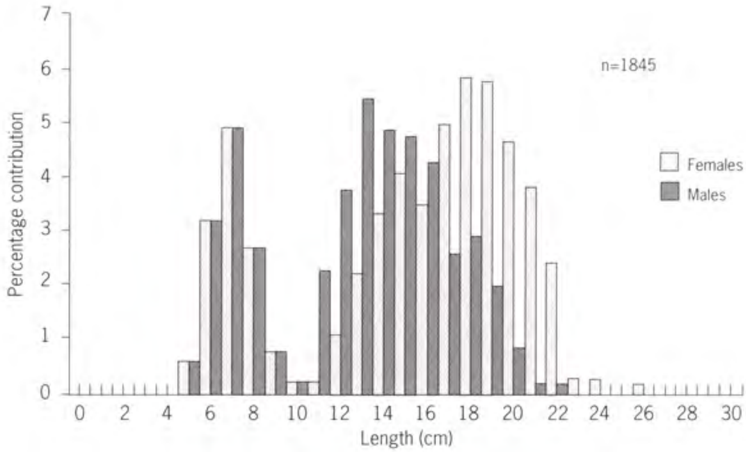
Figure 1 shows the distribution area of *C. linguatula*, based on the points where it appeared during all the cruises from 1994 to 1997 combined. A heterogeneous distribution was observed in the sampled zone since *C. linguatula* was found sporadically at some points in the Alborán Sea and almost constantly in catches from Cartagena Bay (Murcia) towards the North, with increased frequency in the Valencia-Catalonia area.

Figure 1
Distribution area of C. *linguatula* based on its appearance in all MEDITS cruises 1994-1997.

Size compositions

The sizes of the specimens ranged from a minimum of 5.1 cm in length to a maximum of 26.9 cm, with a mean size of 14.7 cm (SD = 4.9). The size interval between 12 cm and 20 cm represented 66% of the total catch. The size range of males was from a minimum of 11.2 cm to a maximum of 22.4 cm, with a mean of 15.4 cm (SD = 2.4); 264 (92.5%) of the specimens were between 12 cm and 19 cm. Females were more numerous (346 specimens), and the size range was between 11.7 cm and 26.9 cm, with a mean of 18.4 cm (SD = 3.1); 96.3% were between 13 cm and 23 cm. The undefined group represented 240 individuals (20% of the total), and the size ranged between 5.1 cm and 24.1 cm, with a mean of 8.2 cm (S.D. = 2.8); however, 8% were between 6 cm and 9 cm. Females were significantly longer (a mean 2.595 cm) than males as determined by a *t*-test with a 95% confidence level. Figure 2 shows the percentages of sizes by sex for total catches and the entire sampling period.

Figure 2
Percentage of size classes by sex of *C. linguatula* in all catches for the 1994-1997 period. Undefined individuals were shared between males and females (50% for each sex).



Bathymetric distribution

The analysis of size classes was based on the four bathymetric ranges determined for the cruises (table 1). The minimum depth for catches was 26 m and the maximum 293 m (a single female 17.2 cm in length). Most of the individuals were concentrated in depth down to 100 m, mainly in stratum B where females were clearly dominant (32% of the total catch), and the mean sizes increased slightly with depth (fig. 3). The different statistical analyses performed (*t*-test, ANOVA) showed that variances in depth between length distributions had no statistical significance, whereas the means differed significantly (with a confidence level of 95%), at least in the first three strata (A-B = 3.1 cm; B-C = 1.7 cm and A-C = 4.8 cm).

Table 1 - Bathymetric distribution of *Citharus linguatula* according to depth strata for all cruises (stratum A: 10-50 m, stratum B: 51-100 m, stratum C: 101-200 m, stratum D: 201-500), showing the percentage of hauls in which *C. linguatula* was present, the percentage of individuals caught relative to the total catch of the species, their size range, mean size, and most abundant size ranges.

Stratum	% occurrence in trawls	% of total individuals	Size range (cm)	Mean size (cm)	Range abund. (cm)
A	20.4	13	5.5-23.1	11.8	6-8
B	42.4	73	5.1-26.9	14.9	12-20
C	36.0	13	6.0-24.0	16.6	15-22
D	1.2	1	17.2	-	-

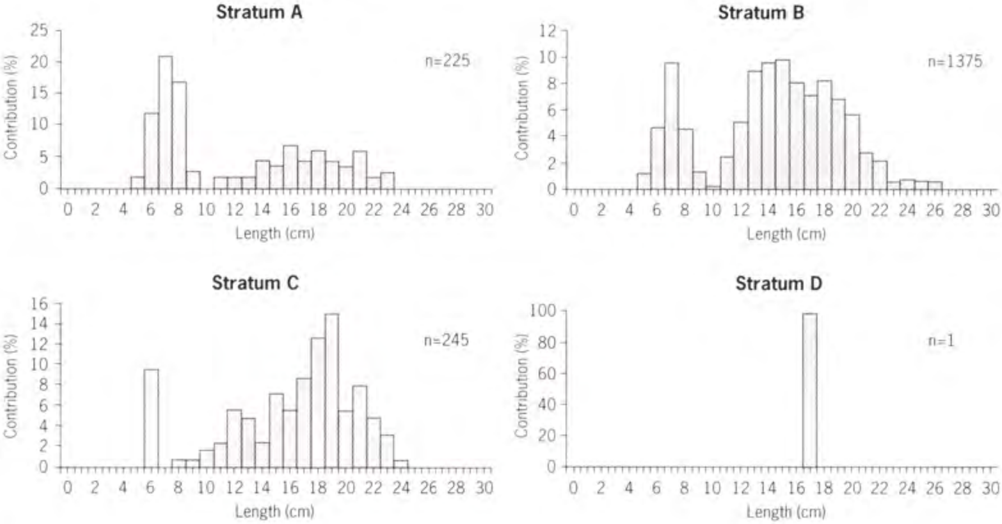


Figure 3
Percentage of the sizes of C. *linguatula* based on depth strata (stratum A: 10-50 m, stratum B: 51-100 m, stratum C: 101-200 m, stratum D: 201-500 m).

Biometric relationships

Table 2 shows the results obtained for estimations of the parameters of the size-weight relationships resulting from the fitting of the data of the different groups (males, females, undefined and the total population), whereas figure 4 shows the graphic representation of these results. The allometry coefficients (b) varied significantly from 3 in all cases, except for the undefined group, indicating a slight positive allometry in the growth of *C. linguatula* with respect to the size at which gonads start to differentiate. There were significant differences between the slopes of the TL-W regressions between the two sexes (ANCOVA: $F = 4.255$, $P<0.05$), as well in the adjusted means (ANCOVA: $F = 9.709$, $P<0.05$).

Table 2 - Estimations of relative growth for the different groups of *C. linguatula* (undefined, males, females and all fish).

Group	a	b	SE (b)	r^2	Sig.	Nb	Range (cm)
Undefined	0.00668	3.0076	0.03180	0.974	ns	240	5.1-24.1
Males	0.00499	3.1008	0.03276	0.972	**	264	11.2-22.4
Females	0.00343	3.2562	0.04672	0.934	***	346	11.7-26.9
All fish	0.00604	3.0474	0.01287	0.985	***	850	5.1-26.9

Size-weight relationship; weight (g) = a * size (cm)^b.
Sig = significance in a Student's *t*-test (*** < 0.001; ** < 0.01; * < 0.05 and ns < 0.1).
SE = standard error.

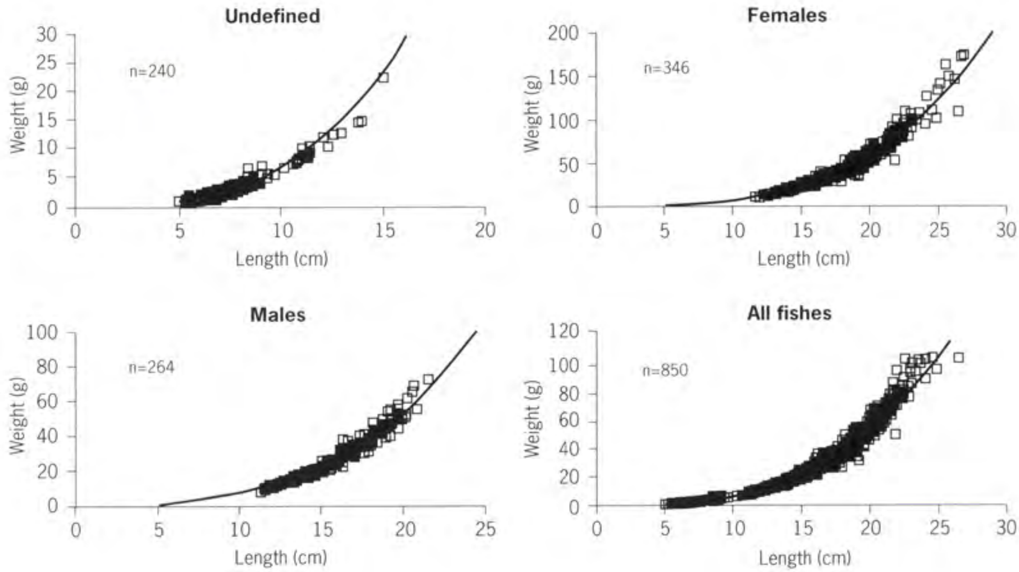


Figure 4
Relative growth curves (length-weight relationship) of C. *linguatula* for the various groups.

Sex ratios and gonadal maturity

Some differences in distribution of the three groups (undefined, males and females) were observed in the percentage by size class of the total catch as mean sizes and ranges for males were lower than for females. Sex ratios by size class were determined from the total number of individuals caught during the cruises. The undefined group represented 28.2% of the total. As a result, males constituted 31.1% of the total, and females were more numerous (40.1%). Males dominated significantly between 11 cm and 14 cm, and females from 18 cm to 26 centimetres. The size at which gonads start to differentiate would appear to be 10 to 11 centimetres. Gonadal maturity, as determined by macroscopic observation, indicated that males and females were in stages 1 or 2 (39.1% and 60.5% respectively for males, and 17.2% and 77.5% for females), whereas only 5.1% of females were found in stage 3 (prespawning).

Growth

The results for the different estimations obtained with the FISAT statistical package are outlined in table 3, which represents the different growth curves obtained by these parameters (fig. 5) as well as the size-age relationship (table 4).

Table 3 - Estimations of VBGF parameters for all individuals of *C. linguatula*.

Group	Period	L_∞ (cm)	K (year $^{-1}$)	t_0	Rn
Total	94-97	33.5	0.28	0.09	0.251
Males	94-97	30.0	0.25	-0.158	0.503
Females	94-97	33.0	0.25	-0.038	0.262

Rn = value of the goodness index.

Table 4 - Length-age key for *C. linguatula* constructed from parameters obtained from FISAT (ELEFAN) for the 1994-1997 period.

	Males		Females		Total	
Age	Length	Mean	Length	Mean	Length	Mean
0	0-7.5	3.8	0-7.5	3.8	0-7.5	3.8
1	7.5-12.5	10.0	7.5-13.2	10.4	7.5-13.9	10.7
2	12.5-16.4	14.5	13.2-17.6	15.4	13.9-18.7	16.3
3	16.4-19.4	17.9	17.6-20.9	19.3	18.7-22.3	20.5
4	19.4-21.7	20.6	20.9-23.6	22.3	22.3-25.0	23.7
5	21.7-23.6	22.7	23.6-25.7	24.7	25.0-27.1	26.1
6	23.6-24.9	24.3	25.7-27.3	26.5	27.1-28.7	27.9
7	24.9-26.1	25.5	27.3-28.6	27.9	28.7-29.8	29.3
8	26.1-26.9	26.5	28.6-29.6	29.1	29.8-30.7	30.1
9	26.9-27.6	27.3	29.6-30.3	29.9	30.7-31.4	31.1
10	27.6-∞	∞	30.3-∞	∞	31.4-∞	∞

Estimations for the total population and for males and females were carried out relative to the different annual distributions. Identification of the normal components of size distributions (Bhattacharya method, FISAT) for a single distribution for the entire period gave values of t_0 = 7.54 cm; t_1 = 14.06 cm; t_2 = 18.61 cm; and t_3 = 21.98 cm, with a confidence level of 95 per cent.

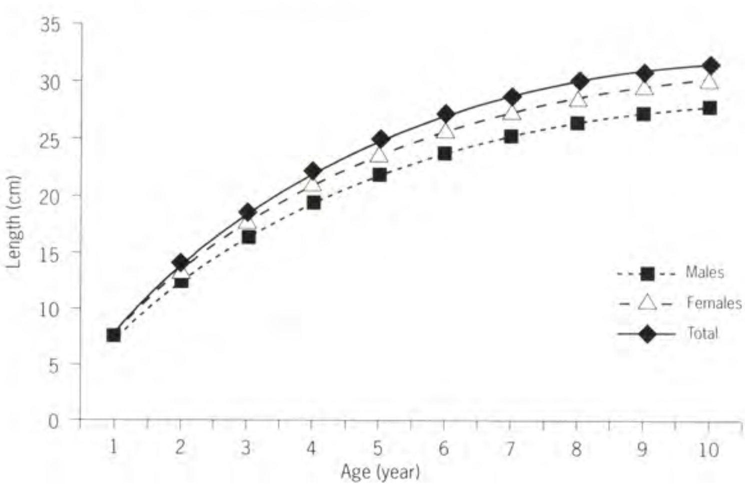


Figure 5
Absolute growth curves (length-age relationship) of *C. linguatula* for the various groups.

Discussion

The spotted flounder *(C. linguatula)* showed a very wide distribution along the peninsular coast, appearing in all areas surveyed, with sporadic occurrence in the Alborán Sea and increasing frequency towards the north. Nevertheless, its bathymetric distribution evidenced an increase in the proportion of larger sizes at greater depths. Although the size ranges in the various strata were similar, the means clearly increased with depth. Specifically, the proportions of the undefined group were greater in the 10 m to 50 m zone (stratum A), whereas the dominant sizes were larger below 50 m (strata B and C) and concentrated mainly in the depth range between 50 m and 100 m (the maximum depth for a catch was 293 m).

The size-weight relationship parameters estimated in this work differed slightly from those of Planas & Vives (1956), who calculated to the millimetre and for eviscerated weight, and Vassilopoulou & Papaconstantinou (1994), who calculated in millimetres and for whole weight. The values of the allometry coefficient b varied significantly from 3 in all cases, and larger values (except in the undefined group) resulted in similar growth curves between the various groups, as previously noted by Vassilopoulou & Papaconstantinou (1994). There were significant differences between growth in weight curves by sexes, so that the growth-in-weight pattern was apparently different in males and females. Despite this situation, we proposed a size-weight relationship for all individuals: weight (g) = 0.00604 * size (cm)$^{3.047}$. Coefficient b was indicative of slight positive allometry throughout the development of the Mediterranean spotted flounder (except the initial stages), with isometric growth until gonadal differentiation.

A dominance in the proportion of males was apparent up to 16 cm, and significant from 11 cm to 13 cm. Gonad differentiation occurred at around 10-11 cm, and females became significantly dominant from 17 cm and were on average 3 cm longer than males. Planas & Vives (1956) noted this sexual dimorphism in sizes, indicating that females are one or two centimetres longer than males at the same age. However, they also noted a variation in sex ratios throughout the year, with males dominating except during the spawning period (August-November) when the ratio balanced out. With certain reservations, this was attributed to horizontal migration. However, the results of the present study suggest that vertical migration is a more plausible explanation as females were concentrated in the 100 m to 200 m stratum. Gonadal maturity during our sampling period indicated that the spawning season had not yet started. According to Planas & Vives (1956), it occurs in the summer, beginning in June-July.

For the estimations of VBGF parameters, it should be noted that our data are provisional and approximate because of the assumptions made in this study. Nevertheless, the parameters estimated were not, in principle, inadequate. The values found show a similarity both for L_∞

and growth rates (K), indicating that they are more adequate than those calculated by sex for the 1994-1997 period. They were quite similar to those of Planas & Vives (1956) for this species, which were based on scale readings. Compared with those estimated by Vassilopoulou & Papaconstantinou (1994) on the basis of otoliths readings, there were differences in the value for L_∞ (25.73 cm), whereas K values were very similar. In general, the parameters calculated for all individuals combined were as proposed and fitted the expression $L_t = 33.5 * (1 - e^{-0.28 * (t - 0.09)})$ obtained from the estimations given by the FISAT package (ELEFAN sub-program). Like Vassilopoulou & Papaconstantinou (1994), we detected a faster growth pattern in females starting in the first year, and a dominance of females in longer sizes. On the whole, females were longer and heavier than males at the same age. Their growth differentiation starts at the beginning of gonadal maturity. The earlier onset of maturity in males and a higher natural mortality, as noted by Vassilopoulou & Papaconstantinou (1994), could account for the greater number of females, which also live longer than males.

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Bathymetric distribution and biological parameters of the blue-mouth, *Helicolenus dactylopterus* (Pisces: Scorpaenidae), on the trawling bottoms off the Iberian Mediterranean coast

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Abstract

A study on the bathymetric distribution, length composition, age and growth of *Helicolenus dactylopterus* was made from the catches of the research cruises MEDITS-ES 94 and MEDITS-ES 95. These surveys are developed annually along the continental shelf and slope off the Iberian Mediterranean coast, within the international bottom trawl project MEDITS. The species was caught throughout the whole bathymetric range surveyed, although its highest frequency of appearance was between a depth of 200 and 400 metres. The maximum yields in abundance and biomass were obtained in the 200-300 m and 600-700 m depth ranges, respectively. The fish length was between 3 and 36 cm, and the mean length, which was 9 cm at 100-200 m and 23.3 cm at 700-800 m, increased with depth. The length-weight relationship obtained showed a negative allometry: Total weight (g) = 0.016223* Total length$^{2.965}$ (cm). The sagittal otoliths had the typical ring pattern attributed to seasonal periodicity. The oldest fish observed were 19 years old, although the bulk of the population (75%) were between 0 and 3 years. The growth parameters of the Von Bertalanffy growth function, calculated from otolith readings for the whole population, were L_∞ = 25.5 cm, K = 0.25 year^{-1} and t_0 = -0.525.

Introduction

The blue-mouth, *Helicolenus dactylopterus* (Delaroche, 1809) (Pisces: Scorpaenidae), is a scorpionfish widely distributed in the eastern Atlantic, from the Norwegian coasts to the south-west coast of Africa (Hureau & Litvinenko, 1986). It is a common and exploited species in the Mediterranean, but it has not been reported in the Black Sea (Bauchot, 1987). In the western Mediterranean, where in the last decades fishing activity has expanded into deeper waters, it is the only scorpionfish occurring regularly along the continental shelf edge and slope. For this reason, it is captured in the bottom trawl fishery targeted to deep-water crustaceans and during the recent exploitation of the non-trawlable slope bottoms using more selective gears (*e.g.* long-lines and gillnets). In addition, this species plays an important ecological role in Mediterranean deep-sea communities at depths below 200 m (Stefanescu *et al.*, 1994).

In the Atlantic, some authors have studied its abundance and biology off Namibia (Morales-Nin, 1980), Cape Blanc (Hoffmann, 1982), the Azores (Isidro, 1987) and Portugal (Cardador & Pestana, 1995). In the Mediterranean, the only available data are from Italian waters, related to the distribution (D'Onghia *et al.*, 1992), diet (Froglia, 1976), age and growth (Peirano & Tunesi, 1986; Ragonese & Reale, 1995; D'Onghia *et al.*, 1996; Romanelli *et al.*, 1997) and exploitation rate (Ragonese & Reale, 1992; Ungaro & Marano, 1995) of this species. The present paper provides information on bathymetric distribution, population structure, age and growth of this species from trawling bottoms off the Iberian Mediterranean coast (fig. 1).

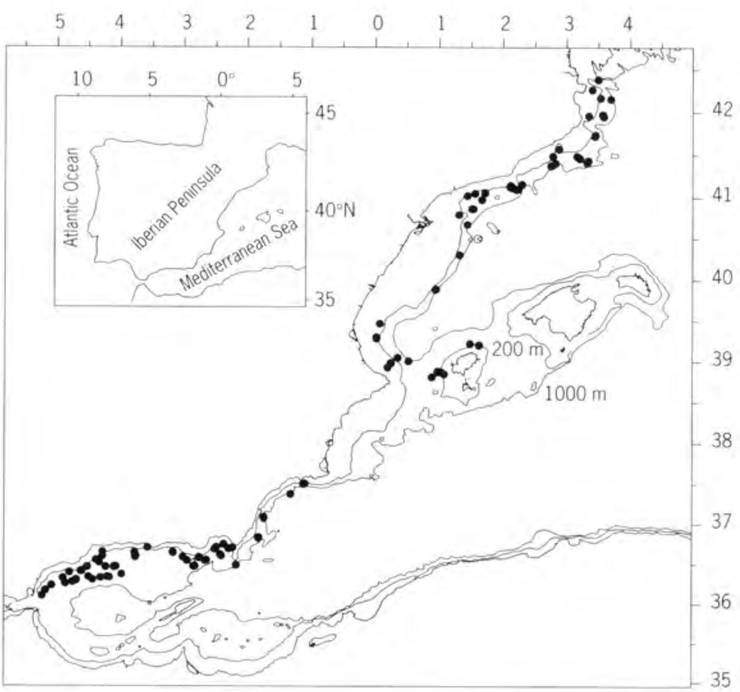

Figure 1
Map of the western Mediterranean, showing the hauls in which *Helicolenus dactylopterus* was caught.

Material and methods

This study was based on the analysis of *H. dactylopterus* catches from a total of 193 bottom trawl hauls between depths of 25 and 785 m, carried out during the research cruises MEDITS-ES 94 and MEDITS-ES 95, developed between April and June in 1994 and 1995. Hauls were carried out using the experimental sampling gear GOC 73, with an effective horizontal and vertical opening of 16.4 and 2.8 m, respectively, and a codend mesh size of 20 millimetres. The duration was 30 min for hauls upper 200 m, and 60 min for hauls below this depth.

In each haul, the catch in weight and number were recorded, and total length (TL, cm) of the specimens (total catch or subsamples) were measured. In addition, fresh weight was determined (TW, g), and sagittal otoliths were extracted from random subsamples, collected to cover the whole size range of the species.

For the purposes of the present study, all analyses were made by combining data from the two sampling cruises (1994 and 1995), and for the whole population (sex was not analyzed in this study). The bathymetric distribution was studied by calculating the frequency of appearance, mean abundance and biomass per haul, and also the length composition for 100 m depth intervals. Whole otoliths were immersed in glycerine and read with a compound microscope using reflected light, following standard procedures. Each otolith was read independently by the first two authors, and only coincident interpretations were accepted.

The length-weight relationships were calculated by applying exponential regression equations, and the Von Bertalanffy growth function was fitted to the age-length relationships obtained from otolith readings by means of Marquardt's algorithm, using the FISHPARM program. As the growth parameters K and L_∞ are inversely correlated, the growth performance index Φ was employed to compare growth rates (Munro & Pauly, 1983). Length frequencies were analyzed by the ELEFAN computer program, to identify the modal groups.

Results

A total of 1694 specimens of *H. dactylopterus* weighing 59 356 g were caught. The species appeared in 44% of the 183 valid hauls analyzed, throughout the whole depth range surveyed (fig. 2). Its appearance frequency increased from 4% in the upper 100 m depth to more than 70% between 100 and 500 m, and then fell to around 50% below this depth. The values of relative abundance and biomass were at a maximum between depths of 200-300 m and 600-700 m, respectively (fig. 2).

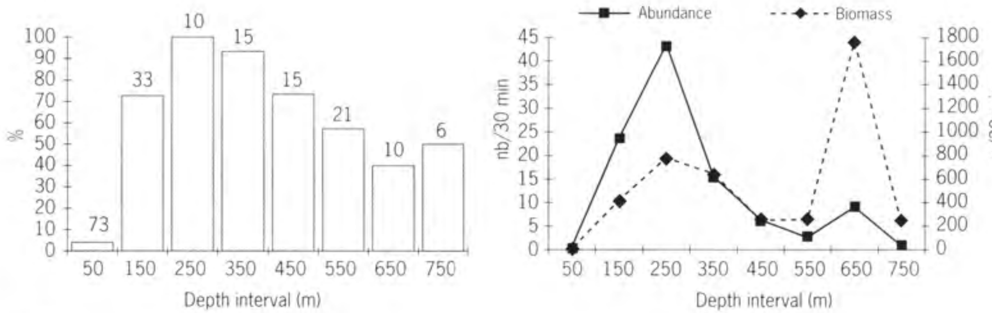

Figure 2
Frequency of occurrence, mean catch for standardized (30 min) haul in number (nb) and weight (g) by depth interval (m) for *Helicolenus dactylopterus*. The central limit of each depth interval and the corresponding number of hauls are also reported.

The length distribution of the 1371 specimens measured ranged between 3 to 36 cm (average: 10.3 cm; SD: 5.73). The specimen size increased progressively with depth, from 8.8 cm in the upper 100 m to 23.2 cm at 700-800 m (table 1). This was due to the fact that fish smaller than 10 cm were very scarce below 500 m and absent below 600 m, while fish larger than 20 cm were caught below a depth of 300 metres. From the analysis of the length frequency distribution for the catches, six distinct modal groups were identified (table 2).

Table 1 - Mean total length, corresponding range and standard deviation (SD) by depth interval of measured (n) *Helicolenus dactylopterus*.

Depth interval (m)	Nb	Range (TL, cm)	Mean length	SD
0-100	6	4-12	8.8	3.13
100-200	574	3-16	9.0	3.23
200-300	322	3-21	7.6	3.94
300-400	230	3-28	10.6	5.72
400-500	88	3-36	10.8	6.40
500-600	54	3-26	16.5	5.74
600-700	91	15-30	22.5	3.34
700-800	6	20-26	23.2	2.03

The results of the length-weight relationship showed a negative allometry (Student's *t*-test, $p < 0.05$):
$TW (g) = 0.016223 * TL^{2.965} (cm)$; $n = 1176$, $r^2 = 0.99$;
which implied a relative decrease of weight in relation to length.

Table 2 - Modal groups of *Helicolenus dactylopterus*, obtained from the analysis of the length frequency distribution.

Group	Nb	Mean length (TL, cm)	SD	SI
1	364	3.74	1.03	-
2	517	9.30	1.05	5.333
3	298	13.25	1.54	3.048
4	162	20.74	2.71	3.520
5	15	24.09	0.49	2.084
6	13	28.91	0.68	8.236

(Nb: number of specimens; SD: standard deviation; SI: separation index).

The otoliths of 807 specimens were examined, of which 14 (1.7%) were considered uninterpretable. All otoliths showed the ring pattern common to teleost fishes, with opaque and hyaline rings laid down around an opaque nucleus. However, one or two hyaline rings were found in the nucleus, which made age determination difficult, especially in the young specimens. The zones of rapid growth, which were more opaque in appearance, were formed frequently by various subunits, separated by fine hyaline rings. The annulae were selected for their greater clarity compared to the false rings, for their regular spacing which followed the Von Bertalanffy growth pattern and for their definition in the whole otolith. The greatest age observed was 19 years (table 3).

Table 3 - Age-length relationship for *Helicolenus dactylopterus*, obtained from the interpretation of the growth rings in otoliths.

Age class (years)	Nb	Range (TL, cm)	Mean length	SD
0	209	3-9	4.4	1.3
1	233	7-14	10.0	1.2
2	98	8-16	12.1	1.5
3	48	12-18	13.9	1.3
4	25	13-20	16.3	1.9
5	37	14-22	18.3	2.0
6	37	17-25	20.6	2.1
7	38	18-26	21.5	2.0
8	20	19-24	21.7	1.4
9	8	20-26	22.4	2.2
10	11	21-28	24.4	2.4
11	15	20-30	24.8	3.1
12	6	22-30	27.2	3.0
13	5	24-28	26.0	1.4
14	1	-	25	-
15	0	-	-	-
16	1	-	28	-
17	0	-	-	-
18	0	-	-	-
19	1	-	36	-

(Nb = number of specimens; SD: standard deviation). As there is no birth-date data on this species, the number of rings was considered as the age.

The growth parameters for the whole population were the following (standard deviation values are between brackets):
L_∞ = 25.5 cm (0.4); K = 0.25 year^{-1} (0.01); t_0 = -0.525 (0.05).

Discussion

The results obtained indicated the presence of *H. dactylopterus* on continental shelf and upper slope bottoms (fig. 2). The maximum abundance at 200-300 m depth could be related to the major availability of food resources at this level. These bottoms are characterized by the presence, in some cases with high densities, of the decapod crustaceans *Alpheus glaber, Calocaris macandreae* and *Goneplax rhomboides* (Cartes *et al.*, 1994), the most important preys for *H. dactylopterus* (Froglia, 1976).

Nevertheless, the relative abundance and biomass curves were different, which is probably due to the mean size increase of the specimens with depth (table 1). This pattern is similar to the one for other deep-sea fishes on the western Mediterranean slope, and can be explained by an ontogenetic migration of the species. Smaller size individuals were concentrated at the shallowest depths within the range occupied by the species, and larger individuals only appeared below certain depths. Thus, recruits of age 0 and juveniles up to 4 years old were restricted to depths shallower than 300 m, while adult fish bigger than 20 cm and 6 years old always appeared below this depth. The widest size range of the species was distributed between a depth of 300 and 600 m, where specimens between 3 and 24 cm (from 0 to 10 years old) were caught.

The otoliths showed a particular growth ring pattern, with numerous false rings. The causes of the formation of these rings are not known, although they are also observed in otoliths coming from a completely different habitat, such as the upwelling zone off Namibia (Morales-Nin, 1980). These types of multiple rings are common in other species from the continental slope of the western Mediterranean. Although the type of sampling carried out did not allow the annual periodicity of the rings to be determined, they were considered as annual because of their similarity with the data reported for the species. Nevertheless, further attempts to validate the ageing method used and to compare age-length relationships between areas with different oceanographic conditions are needed to improve the knowledge of the growth patterns of this species in the western Mediterranean.

Our preliminary data suggest that *H. dactylopterus* is a long-lived species, with numerous age classes in the population. The analysis of the size frequency detected at least 6 classes, whereas the otolith readings indicated 19. This age of big specimens could have been underestimated by reading whole otoliths. However, as a big fraction of the studied population corresponds to fish older than 10 years old and bigger than 25 cm TL in length, the possible error might be negligible. This population structure could also affect the low estimation of the asymptotic length (L_∞ = 25.5 cm TL) in relation to the maximum length observed (36 cm TL).

A good correlation was found between the three first modes and the average sizes, calculated by otolith readings, corresponding to age classes 0, 1 and 2-3 (tables 2 and 3). However, length frequency analysis could not identify modal classes in the older age groups, due to growth variability and length overlapping. The growth parameters obtained in this study showed some differences compared with those reported from other areas in the Mediterranean (table 4). Nevertheless, similar results are obtained by comparing growth performance indexes (Φ). The differences registered could be due to differences in the range of sizes sampled, the methodology applied (weighed or not-weighed regression, individual observations or mean values, inclusion or exclusion of the edge classes, etc.), and to variations in growth caused by the different characteristics of the study areas. The basic problem to study age and growth of this species consists in the more or less gradual reduction in the availability to the usual bottom trawl of the big specimens, and the consequent bias in the age estimation. Although the verbally reported existence of very large fish (up to 50 cm TL) has not been scientifically documented (reaching only up to 38-41 cm TL), despite the trials with trammel nets and bottom long lines on rocky bottoms developed recently (S. Ragonese, comm. pers.), it is likely that the Von Bertalanffy parameters, derived by trawl data, tend to underestimate the asymptotic length (L_∞) and overestimate the growth coefficient (K).

Table 4 - Growth parameters for *Helicolenus dactylopterus*, reported by several authors in different areas of the Mediterranean.

L_∞ (cm)	K (year^{-1})	Φ	Area	Author
70.7	0.045	2.35	Ligurian Sea	Peirano & Tunesi (1986)
39.2	0.127	2.29	Sicilian Channel	Ragonese & Reale (1995)
30.7	0.156	2.17	Ionian Sea	D'Onghia *et al.* (1996)
29.9	0.190	2.23	Adriatic	Ungaro & Marano (1995)
25.5	0.250	2.21	Iberian coast	Present study

(L_∞: asymptotic length; K: growth coefficient; Φ: growth performance index).

Taking into account the only available information on first maturity of the species in the eastern Atlantic, which has been estimated at around four years (Boutière, 1958), the age composition of the catches, in which specimens between 0 and 3 years old represented 75% of the studied samples (fig. 3), showed a population structure dominated by recruits of the year and juvenile fish. *H. dactylopterus* is probably a species with a distribution, at least in the larger sized specimens, that shows a clear preference for rocky bottoms with an irregular slope which is not very accessible to trawling, both in Mediterranean (Massutí & Massó, 1975; Romanelli *et al.*, 1997) and Atlantic waters (Isidro, 1987). Thus they are caught with traps as an accompanying species in the *Plesionika edwardsii* fishery (González *et al.*, 1992) and it is one of the species characteristic of the ichthyofauna associated with submarine canyons (Stefanescu *et al.*, 1994). During the cruises, the hauls that registered a greater yield of this species were undertaken at depths of 300, 647 and 620 m, with the capture of large-sized specimens. In these catches, the accompanying fauna and small tears in the net indicated a type of rocky bottom. Therefore, the scarcity of adult specimens detected during the cruises, cannot be attributed only to a higher mortality of the species. The change of habitat throughout its life cycle and the type of gear used, which is not appropriate for sampling these bottoms, could have influenced the abundance values of the large-sized specimens.

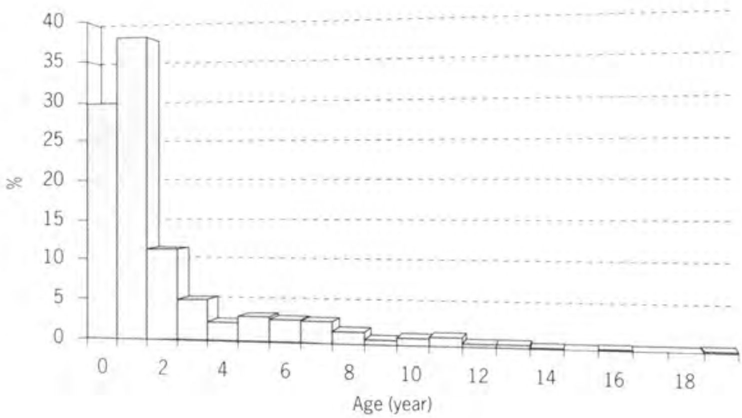

Figure 3
Age composition of the catches (n = 1694) of *Helicolenus dactylopterus* from trawling bottoms of the Iberian Mediterranean coast, calculated after extrapolation by using the length frequency distribution and the age-length relationship.

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Acknowledgements

The authors wish to thank all the participants in the cruises as well as the Captain and crew of R/V *Cornide de Saavedra*, for their help during the sampling, and Dr C. Rodgers for help with improving the English. This work was supported by the project MEDITS/DG XIV/IEO/054.

Chapter IV

Spatio-temporal distribution

Temporal variability of demersal species in the Gulf of Lions from trawl surveys (1983-1997)

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Abstract

The aim of this study was to analyse the middle term variations of fourteen groundfish species in the Gulf of Lions, based on the results of ten bottom trawl surveys carried out between 1983 and 1997 on the continental shelf of the area.

Two types of analysis were performed. The presence/absence of the concerned species during the different surveys was compared to detect change in their relative frequency and rank. Mean biomass and abundance indices were estimated for each species and survey. These indices were employed to take into account the quantitative variations that could be related to stock abundance fluctuations. Overall, no distinct changes could be shown except for *Raja clavata*, which exhibited a clear declining trend. The reliability of abundance indices estimated from trawl surveys was discussed from some of the examples cited in this work.

Introduction

Estimates of the abundance of groundfish can be drawn from data from two sources: (i) fishery dependent data, *i.e.* catch and effort statistics from commercial fisheries, and (ii) fishery independent data, *i.e.* data from scientific surveys. In the Gulf of Lions (western Mediterranean), the two types of data were collected for demersal resources since the early eighties. Stock assessment methods based on the first type of data were used for some of the commercially important species (hake, sole, bass, seabream) of the demersal fishery during the last decade (Aldebert & Recasens, 1996; Farrugio & Le Corre, 1996). The first standardized series of trawl surveys began in 1983 and have continued till now through different projects. These data were used for ecological studies on species assemblages (Gaertner, 1997; Gaertner *et al.*, 1998) or biodiversity (Aldebert, 1997). The abundance indices of angler fish were also analyzed for the years 1983 to 1987 (Liorzou *et al.*, 1989).

The aim of this study was to analyse the variations in frequency, distribution and abundance of some of the demersal species from these trawl surveys and to discuss the reliability of these surveys for abundance estimates.

Material and methods

The data used for the present study were issued from ten bottom trawl surveys carried out by the Fishery Laboratory of Ifremer-Sète on the continental shelf and the upper part of the slope of the Gulf of Lions between 1983 and 1997. All these surveys were conducted to provide quantitative biological data on demersal resources *i.e.* geographic distribution, biomass and abundance indices.

The first series (CHALIST surveys) was performed for a national programme. The RECLIO survey was part of a European contract focusing on the seasonal distribution of the juveniles of the main demersal fish species. The second series, 1994-1997, was carried out within the context of the MEDITS project, an international European programme now in progress. For the present study, only catches on the continental shelf (less than 200 m depth) were taken into account.

The sampling design remained similar throughout the whole period (Liorzou *et al.*, 1989; Campillo *et al.*, 1989; Bertrand *et al.*, 2000):

- same geographic coverage (the entire trawlable area in the Gulf of Lions);
- similar period of the year (June);
- random sampling within a previous depth stratification, the number of hauls in each stratum being proportional to the total area of the stratum (table 1);
- same duration of hauls (half an hour);
- estimation of the area fished during each haul;
- same procedure to analyse the fish caught per haul during the whole period: identification of every species (Fischer *et al.*, 1987; Whitehead *et al.*, 1984-1986), weighting, numbering and measuring individuals.

Table 1 - Characteristics of the sampling designs.

Date	Research Vessel	Surveys	Mesh size codend (mm)	Gear	Nb of Hauls	Depth 0-25 m	Depth 25-49 m	Depth 50-99 m	Depth 100-149 m	Depth 150-199 m
06/83	*Ichthys*	CHALIST 1	40	2 panels	48	4	6	28	9	1
06/85	*Roselys II*	CHALIST 2	40	VO 1.8 m	69	6	10	41	12	0
06/86	*Roselys II*	CHALIST 3	40	TS 10-12 m	62	4	7	31	18	2
06/87	*Roselys II*	CHALIST 4	40		71	3	9	34	25	0
06/88	*Roselys II*	RECLIO 1	40+16	2 panels + cover VO 1.8 m	55	6	8	25	15	1
05-06/92	*Roselys II*	CHALIST 5	40	2 panels VO 1.8 m	69	6	12	39	12	0
06/94	*L'Europe*	MEDITS 94	20	2+2 panels	55	2	10	32	11	0
06-07/95	*L'Europe*	MEDITS 95	20	VO 2.5 m	54	2	10	32	10	0
06/96	*L'Europe*	MEDITS 96	20	TS 15-17 m	54	2	10	32	10	0
06/97	*L'Europe*	MEDITS 97	20		63	4	11	38	10	0

VO: vertical opening, TS: trawl spread.

However, the surveys were not carried out with the same research vessel, nor using entirely identical gear. In particular, the codend mesh size significantly changed between the series (table 1). Also, the time series shows some gap, mainly a three-year period between 1989 and 1991, so that one can distinguish two shorter homogeneous sub-series. Caution is therefore needed for comparing the results from a quantitative point of view throughout the whole period.

Fourteen fish species (table 2) were retained for the present study. The criteria for their selection were typical benthic or demersal behaviour, abundance in the Gulf of Lions and/or high interest for the demersal fishery. All belong to the list of the main reference species retained for the MEDITS project.

Table 2 - List of the reference species.

Family	Species	Code	Common name
Rajidae	*Raja clavata*	Raja cla	Thornback ray
Merlucciidae	*Merluccius merluccius*	Merl mer	European hake
Gadidae	*Micromesistius poutassou*	Micm pou	Blue whiting
Gadidae	*Phycis blennoides*	Phyi ble	Greater forkbeard
Gadidae	*Trisopterus minutus capelanus*	Tris cap	Poor cod
Mullidae	*Mullus barbatus*	Mull bar	Red mullet
Mullidae	*Mullus surmuletus*	Mull sur	Striped red mullet
Sparidae	*Pagellus acarne*	Page aca	Axillary seabream
Triglidae	*Eutrigla gurnardus*	Eutr gur	Grey gurnard
Citharidae	*Citharus linguatula*	Cith mac	Spotted flounder
Scophthalmidae	*Lepidorhombus boscii*	Lepm bos	Fourspotted megrim
Soleidae	*Solea vulgaris*	Sole vul	Common sole
Lophiidae	*Lophius budegassa*	Loph bud	Black-bellied angler
Lophiidae	*Lophius piscatorius*	Loph pis	Angler

Descriptive analyses, mainly based on the presence/absence of fish species, were carried out to show possible trends for each species. Diagrams were used to indicate modifications both in absolute frequency and relative rank of species. In these diagrams, frequency is equal to the number of positive hauls against the total number of hauls within the survey.

The estimation of the mean biomass and abundance indices was based on the stratified-random sampling method (Cochran, 1977), these indices being expressed by weight (kg) or number per area unit (km^2). Six strata were defined from the depth: (10-50, 50-100, 100-200 m) and on both sides of the 4° East. These indices are calculated as follow (Souplet, 1996):

Notations:

A total surface of the area

N number of strata in that area

A_i surface of stratum i

W_i relative weight of stratum i in the area

n_i number of hauls in stratum i
$A_{i,j}$ surface trawled by haul j in stratum i
f_i sampling fraction in stratum i
$x_{i,j}$ measured value in haul j

with $W_i = \frac{A_i}{A}$ and $f_i = \frac{\sum_{j=1}^{n_i} A_{i,j}}{A_i}$

Mean value of x by unit of surface in stratum i: $\bar{x}_i = \frac{\sum_{j=1}^{n_i} x_{i,j}}{\sum_{j=1}^{n_i} A_{i,j}}$

Variance of the value in stratum i: $\tilde{S}^2_{x_i} = \frac{1}{n_i - 1} \sum_{j=1}^{n_i} A_{i,j} \left(\frac{x_{i,j}}{A_{i,j}} - \bar{x}_i \right)^2$

Abundance index in the area: $I = \sum_{i=1}^{N} W_i \bar{x}_i$

Variance of this index: $var(I) = \sum_{i=1}^{N} \frac{W_i^2 \tilde{S}^2_{x_i}}{\sum_{j=1}^{n_i} A_{i,j}} (1 - f_i)$

The term $(1-f_i)$ could be neglected because f_i is in general very small.

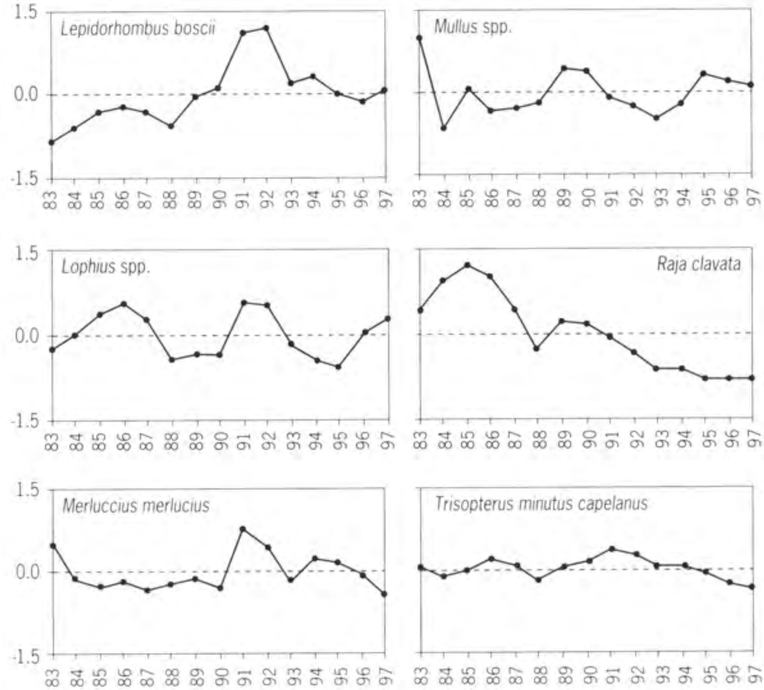
Trends in the landings of the reference species from the Sète auction were also taken into account (fig. 1). This port, which is very central in the Gulf, represents more than a third of the total French landings of demersal species from the Gulf of Lions. These landings reflect the production of a trawler fleet that is composed of bottom, mixed and pelagic trawlers (Taquet *et al.*, 1997). They may be considered as a good indicator for the general landing trends from the Gulf of Lions (Aldebert, 1997).

Results

Presence and frequency

The fourteen retained species were caught during all surveys. The rank-frequency diagrams established for each survey show that three species were dominant throughout the period (fig. 2). These species, *Merluccius merluccius*, *Trisopterus minutus capelanus* and *Eutrigla gurnardus*, always ranked above the others. Their very high frequency, close to 100%, corresponds to a wide distribution within the sampled area.
A second group is made up of species for which frequency as well as rank remain rather constant from 1983 to 1997. In this group, one can find mainly species with typical benthic behaviour such as flatfish, anglerfish and red mullets. The stability of the rank seems to be linked to the level of frequency: higher variability was observed for species

Figure 1
Variations of landings in the Sète auction for some of the reference species, expressed as the difference between the annual production and the mean production for the years 1983-1997.



whose frequency was lower. Such a situation was observed for *Lepidorhombus boscii* whose frequency seemed to lessen slightly during the most recent period. This does not clearly reflect in the distribution area (fig. 3).

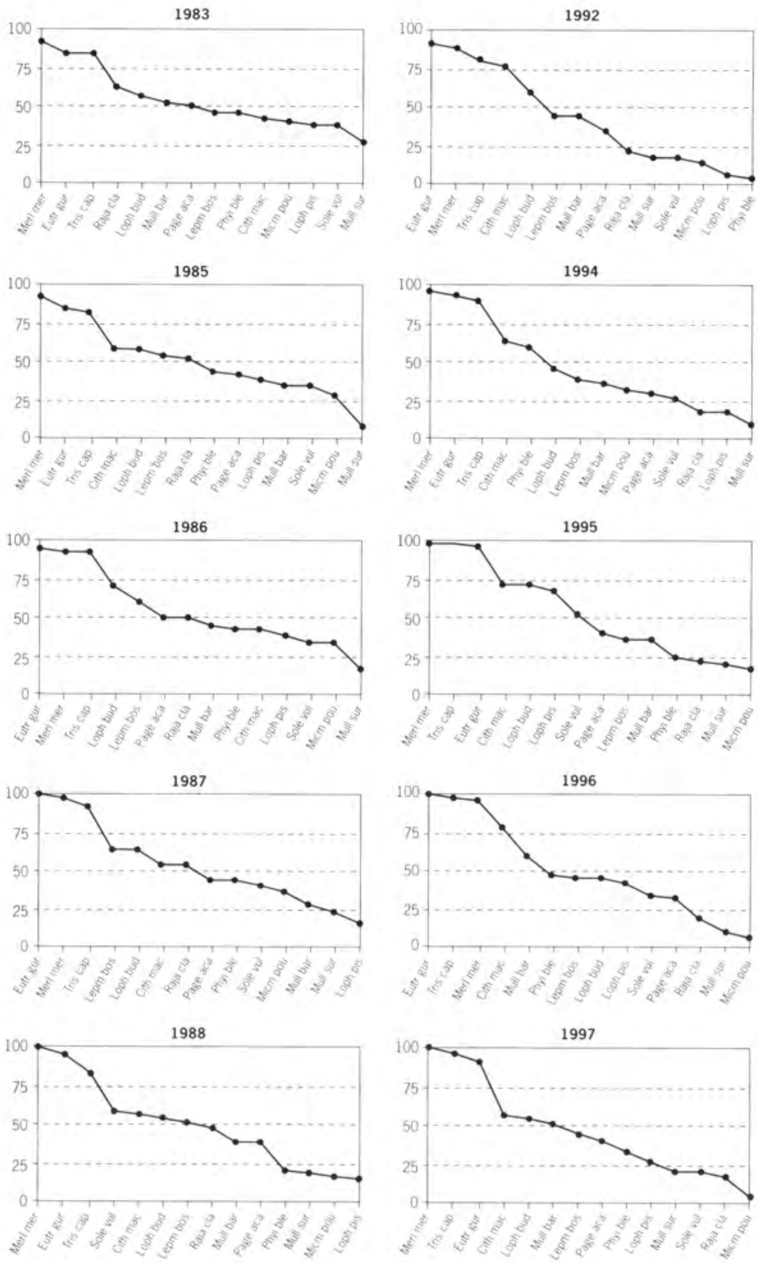
Only two species should be considered separately. A very high variability was observed for the blue whiting, especially during the first period; the low frequency since 1992 could be considered as a possible decreasing trend, this interpretation being discussed further on.

The case of *Raja clavata* was clearer: a regular decrease in frequency was observed throughout the period, as well as a change in rank (4^{th} rank in 1983, 13^{th} in 1997). The decreasing trend was quite evident in this case. This reduction was characterized by a decrease in the distribution area within the gulf with a dividing of the zone, the larger remaining zone being at the border of the shelf (fig. 3).

Abundance and biomass

The three most frequent species (*M. merluccius, T. minutus capelanus* and *E. gurnardus*) were also those with the highest biomass indices (usually between 50 and 100 kg/km^2, fig. 4) and abundance indices (often between 1,000 and 5,000 ind./km^2). It should be noted that these high numbers were due mainly to catches of juveniles, *i.e.* to the recruitment. Another species, *Lophius budegassa*, may be included in the same group for its biomass indices, but had lower abundance indices (about 100 ind./km^2). In this group, the highest interannual variations were

Figure 2
Rank-frequency diagrams for the fourteen reference species on the continental shelf of the Gulf of Lions. Correspondences between abbreviated and full names are given in table 2.



encountered for *M. merluccius*. Particularly, a high value was identified for 1988 after a decrease between 1983 and 1987. A regular decrease occurred during the last four years (1994-1997).

Another group may be identified by regrouping five species: *Citharus linguatula*, *Lepidorhombus boscii*, *Mullus barbatus*, *Pagellus acarne* and *Solea vulgaris*. Their biomass indices were regularly lower (about 10 kg/km^2)

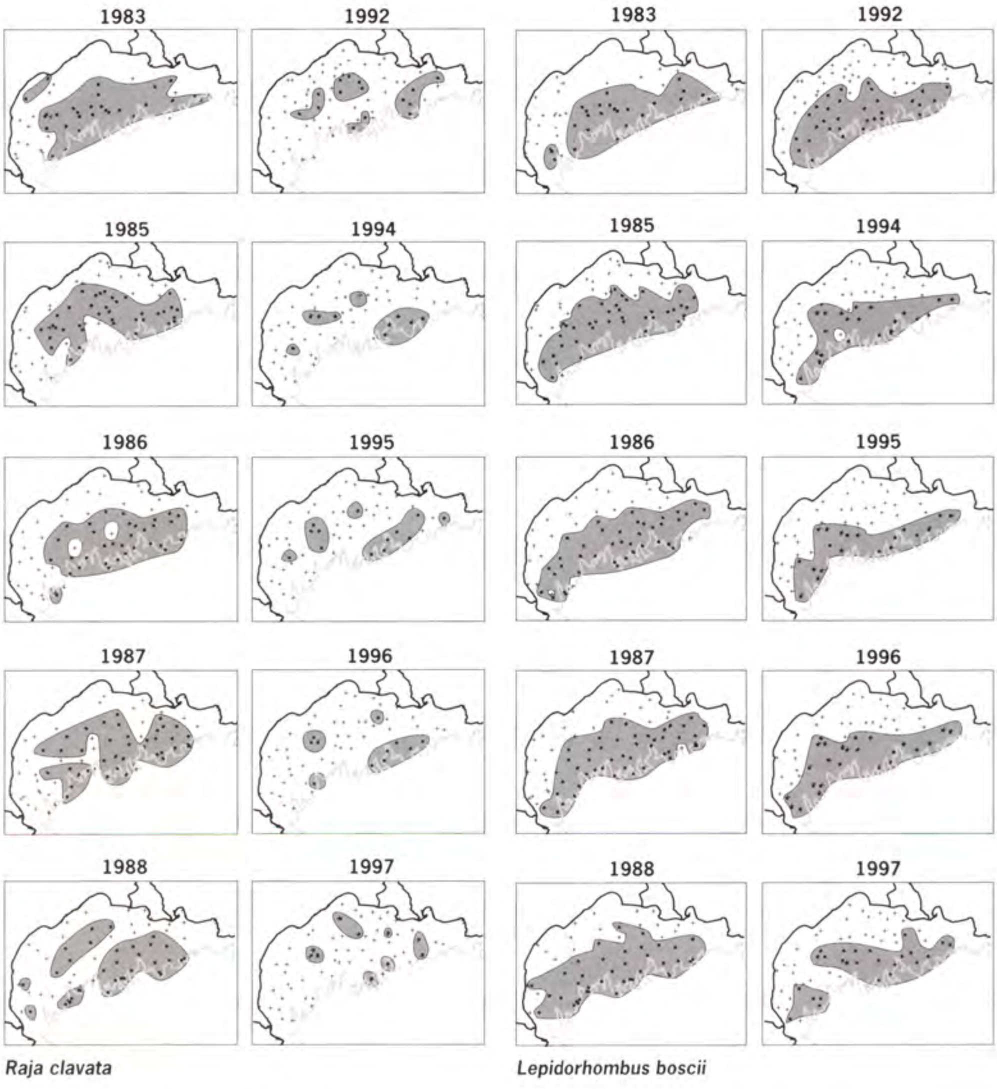


Figure 3
Distribution areas of *Raja clavata* (left) and *Lepidorhombus boscii* (right) in the Gulf of Lions between 1983 and 1997, from presence/absence within the trawl surveys (grey area: presence, + : absence).

than in the previous group. The abundance indices usually fluctuated between 80 and 500 ind./km^2, except for the sole (10 to 80 ind./km^2). The less abundant species in this series were *Mullus surmuletus* and *Phycis blennoides* (usually less than 10 kg/km^2). Regarding *Micromesistius poutassou* and *Lophius piscatorius*, the biomass indices showed very high variations from year to year, without particular trend.

Finally, one species, *R. clavata*, showed a very constant abundance decrease throughout the entire period. Indeed, the biomass index declined from 90 kg/km^2 in 1983 to 5 kg/km^2 in 1997. Despite some discrepancies between the two series of indices (biomass and abundance) and particularly a high variability during the second period, the two indices follow the same general trend.

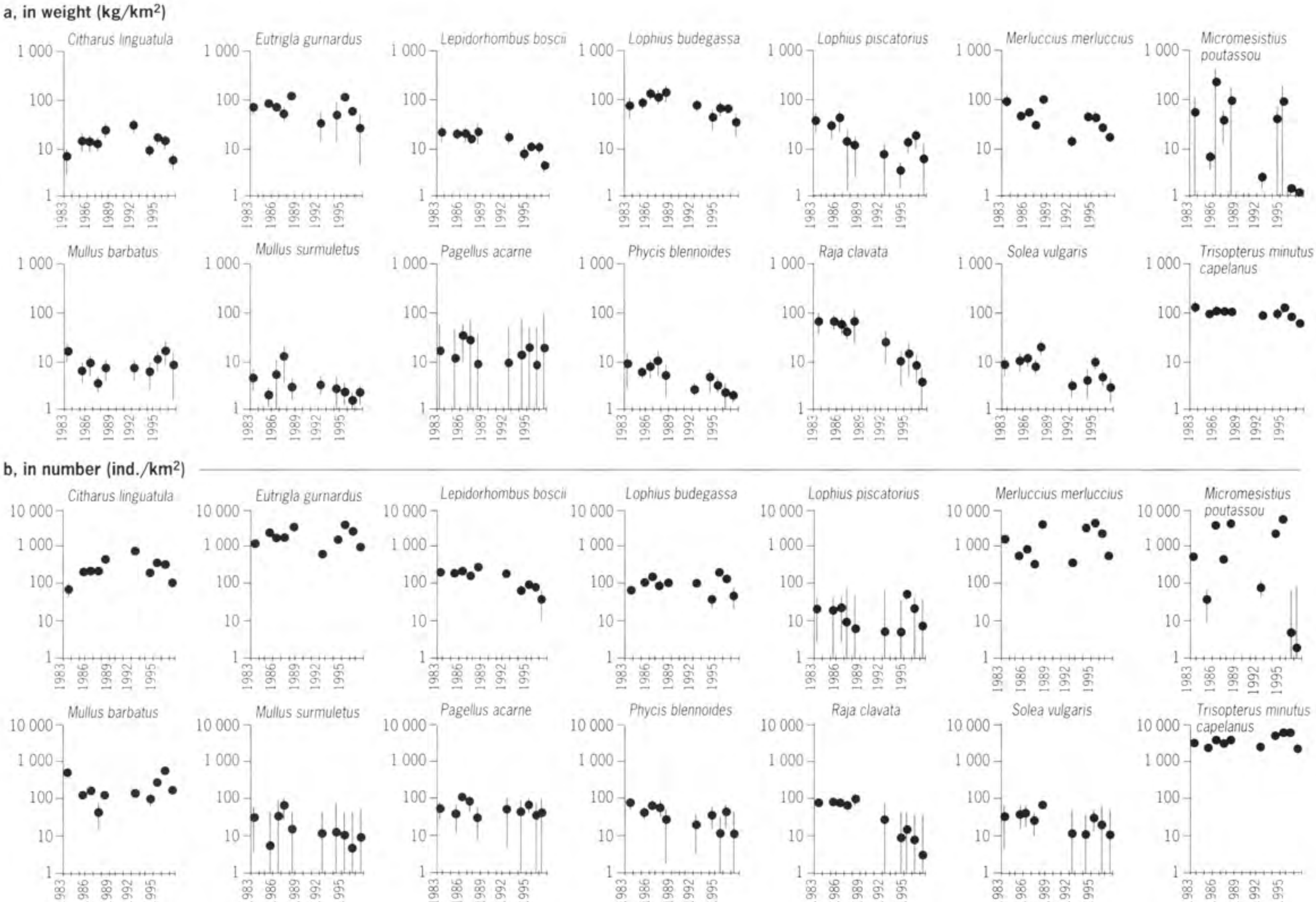


Figure 4 - Biomass and abundance indices for the fourteen reference species in the Gulf of Lions (10-200 m) from trawl surveys between 1983 and 1997.

Discussion

Most of the selected species belong to the stable component of the species assemblage described by Gaertner *et al.* (1998) for a large part of the continental shelf of the Gulf of Lions. Using multitable analysis, these authors showed that the stable component of the demersal species assemblages in the area is closely related to the depth. They also emphasized the stability of this structure during the time of their study (1983-1992).

One of the main problems in estimating the abundance of fishery resources is the varying catchability of the species due to the sampling procedure and gear. Factors that determine fish catchability include (i) the areal and vertical distribution of fish in relation to the fishing gear, (ii) the fish behaviour in the vicinity of the fishing gear, and (iii) the selection properties of the fishing gear. As bottom trawl surveys are usually multipurpose and multispecies surveys, they do not offer an equal catchability for all species (Godø, 1994). Also, the design of the sampling grid will have a different impact according to the distribution of the various species. The protocols of the surveys used here had such limiting factors, so that the confidence level of the results differed according to the species, especially regarding the quantitative estimators.

An illustration of a case of poor reliability of the demersal surveys is provided by the blue whiting whose abundance and biomass indices showed very high variations with a high variance. This is mainly due to the habitat of *M. poutassou* and to its shoal behaviour. In the area, this mesopelagic species has a wide vertical distribution and is found frequently to a 400 m depth (Quéro, 1997).

The high variances of estimators for *P. acarne* must also be related to gregarious behaviour, which is typical of many Sparids. However, in this case, the absolute value of abundance indices remained quite stable for all surveys.

For the majority of the species, the confidence intervals of the estimators were rather low, thus providing a valuable indication of the abundance as well as revealing the changes in population structures and their distribution over time. This was the case for the gurnard, anglerfish, flatfish, ray, and other Gadidae (*M. merluccius, T. minutus capelanus, P. blennoides*). Only very short-term variations may be identified for these species. The observed variations within the entire period need to be considered with caution because of a possible effect of the changes in the sampling procedures between the two main periods. Taking this consideration into account, the most stable species within the whole period, both from the survey estimates and the landings is *T. minutus capelanus.*

M. merluccius is the most important species for the demersal fishery in the area. It is also one of the most abundant in weight and number in the trawl surveys, with a high proportion of small sized individuals.

In the present series, the indices estimated for *M. merluccius* could be affected by the change in the sampling gear throughout the period: the relatively high abundance index pointed out in 1988, as well as the increase between 1992 and 1994, may be related to the changes in the mesh size of the trawl codend and therefore to a change in selectivity. This is particularly relevant because most of the hake caught with the gears having a small mesh size codend (20 mm) are smaller than the selection size of the mesh (40 mm) used during the first survey series (Dremière, 1980).

With regard to yearly recruitment, the results need to be interpreted with the date (June) of the surveys kept in mind. This is particularly important for hake whose long and variable spawning period (GFCM, 1982; Gonzáles-Garcés & Pereiro, 1994) can lead to changes in the date of yearly recruitment. Nevertheless, a separate analysis of the two series, *i.e.* the one with larger mesh size (1983-1987) and the other with small mesh size (1994-1997) suggests a decrease in the biomass indices for this species within each of the shorter periods. This signal of a possible decrease in hake biomass over the last few years has to be considered in relation with the diagnosis of Aldebert & Recasens (1996), who reported that the present level of exploitation of this species in the Gulf of Lions was well beyond its optimal biologic level. It should be noted that commercial landings in Sète showed a similar decreasing trend during the recent period. The integration of complementary data, particularly the length distributions available from the surveys, will be very useful for completing the analysis.

Clear evidence of changes in the number of Elasmobranchs species in the Gulf of Lions was described by Aldebert (1997) throughout the last decades. *R. clavata* is one of the two species of Rajidae still remaining in the area. The situation observed over the last fourteen years, particularly the decrease in the biomass indices as well as the reduction of its distribution area, may constitute a strong signal of risk for the survival of this species in the Gulf of Lions. It is well known that Elasmobranchs, which have a low fecundity rate and a long incubation time, are highly vulnerable to the fishery. The decline of species may affect very large areas, as it has been pointed out for *Raja laevis* in the North-West Atlantic (Casey & Myers, 1998). One may conclude that the impact of exploitation is rather clear for *R. clavata* in the Gulf of Lions, as for other Elasmobranchs in that area (Aldebert, 1997).

In conclusion, extensive bottom trawl surveys provide much information on a very wide diversity of species. For quantitative analysis, however, it is very important to consider carefully the reliability of the data obtained with reference to the sampling strategy and the behaviour of the sampled species. The above examples provide illustration of the very wide diversity of situations which may be encountered.

Short trawl survey series allow only the identification of very strong variations, as was the case for *R. clavata*, whose abundance and distribution clearly decreased in the Gulf of Lions over the last fourteen years. For most of the species, short-term variability masks other trends that might be progressively characterized by longer series. Although the replication of surveys year after year is not necessary to complete the characterization of the main species assemblages in the Gulf of Lions (Gaertner, 1997), a standardized repetitive survey at a yearly scale would supply very relevant information for "real time" monitoring of the fisheries.

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Distribution and abundance of *Aristeus antennatus* (Decapoda: Dendrobranchiata) along the Mediterranean Spanish coast

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Abstract

This study analyses the geographical pattern, size structure and relative abundance of *Aristeus antennatus* on the basis of experimental trawl surveys carried out in the spring of 1994, 1995, 1996 and 1997 along the Mediterranean Spanish coast. The species occurred at a depth range of 414 m to 786 m on the upper and middle slopes. The percentage of occurrence increased with depth, reaching a maximum at 600-800 m where specimens were found in 75% or more of samples. Sizes ranged from 16 mm to 66 mm carapace length (CL) for females and from 16 mm to 36 mm CL for males. There was a trend toward larger size at greater depths, although young individuals (smaller than 20 mm CL) were observed at practically all depths. The areas with high relative abundance were the northeastern Alborán Sea, the Alicante zone together with Valencia and the Eivissa Channel, and the northern Catalan area.

Introduction

The red shrimp *Aristeus antennatus* is a deep-water penaeid of importance to commercial fishing. Its geographic range includes the Mediterranean and the Atlantic coast from Lisbon (Portugal) to the Cape Verde Islands. Commercial trawling catches are made on the continental slope at depths of 350 to 850 m. However, in the western Mediterranean, bathymetric distribution reaches depths of 2,200 m (Cartes, 1993). The habitat of *A. antennatus* is closely related to the presence of canyons and submarine channels as well as trenches of the continental slope (Abelló *et al.*, 1988). The life cycle model follows the general pattern described by several authors (Massutí & Daroca, 1978; Orsi Relini & Relini, 1979; Arrobas & Ribeiro-Cascalho, 1987; Sardà & Demestre, 1987; Demestre & Fortuño, 1992). Its fishing and dynamics have also been studied (Demestre & Lleonart, 1993; Ragonese & Bianchini, 1996).

The purpose of this study was to analyse the geographical pattern, size frequency distribution and relative abundance of A. *antennatus* over a wide area using a standardized methodology.

Materials and methods

In the context of the MEDITS (DG XIV: MED 93/018) research project, random-stratified trawl surveys were performed every year between 1994 and 1997. The study area included the continental shelf and the upper and middle slopes from the Strait of Gibraltar to Cape Creus (excluding most of the Balearic Islands). The area was subdivided into eight geographical sectors: (1) northwestern Alborán Sea, (2) northeastern Alborán Sea, (3) Gulf of Vera, (4) Alicante zone, (5) Valencia zone, (6) Ebro Delta zone, (7) northern Catalonian zone, and (8) Eivissa Channel (fig. 1).

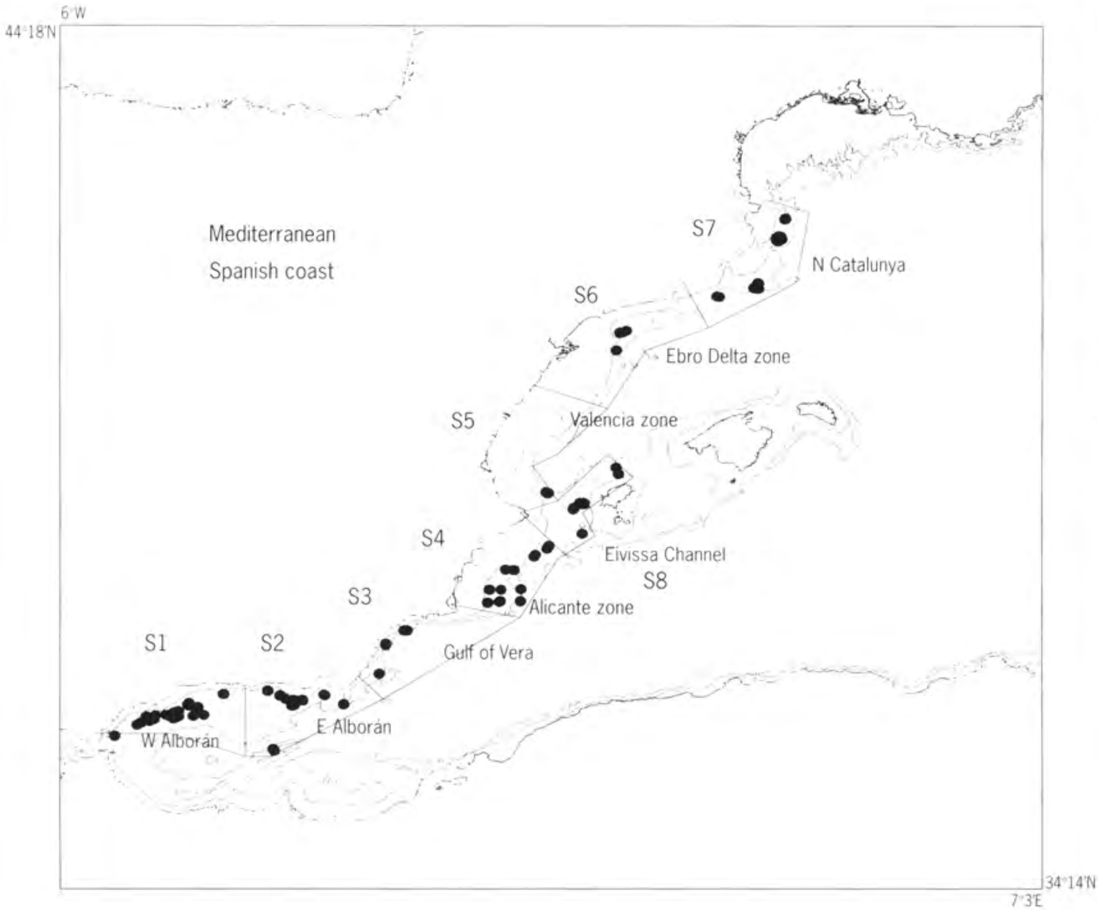


Figure 1
Occurrences of samples in the study area (western Mediterranean Spanish coast).
S1 = northwestern Alborán Sea;
S2 = northeastern Alborán Sea;
S3 = Gulf of Vera;
S4 = Alicante zone;
S5 = Valencia zone;
S6 = Ebro Delta zone;
S7 = northern Catalonian zone;
S8 = Eivissa Channel.

These sectors are of similar size and were defined by geomorphologic and oceanographic features. A total of 389 hauls were performed from 25 m to 786 m depth.

Sampling was conducted during daylight with a 60-min tow, using a 20 mm mesh codend liner with a 2.8 m vertical opening and an 18.7 m headrope.

All specimens of *A. antennatus* in samples were sexed and measured (carapace length, CL, in mm); and the weight in grammes was determined for all samples. Cluster analysis was applied to male and female size frequency samples using Czekanowski's percentage similarity index and the UPGMA as aggregation algorithm (Abelló *et al.*, 1997). Samples with fewer than twenty specimens of either sex were excluded from the data matrix. The length-frequency compositions of each main assemblage and the global size frequency of each geographical sector were represented graphically by sex.

Mean relative abundance (nb/h) and biomass (g/h) were obtained by averaging the hauls of each 100 m-depth interval by sector and year.

Results

A total of 60 occurrences of *A. antennatus* were analyzed among 389 samples collected. The percentages of occurrence as a function of sector and depth stratum are shown in table 1.

Table 1 - Percentage of occurrence (OCC) of *A. antennatus* by sector and depth strata.

	S1-WALB		S2-EALB		S3-VERA		S4-ALIC		S5-VALE		S6-DELT		S7-NCAT		S8-EIVI		MEAN	
Depth (m)	nb	OCC	nb	OCC	nb	OCC	nb	OCC	nb	OCC	nb	OCC	nb	OCC	nb	OCC	nb	OCC
0-50	4	0	3	0	2	0	8	0	2	0	12	0	6	0	0		37	0
51-100	13	0	6	0	2	0	21	0	16	0	38	0	21	0	0		117	0
101-150	6	0	3	0	0	-	6	0	9	0	9	0	20	0	1	0	54	0
151-200	1	0	2	0	2	0	7	0	0	0	1	0	4	0	0		17	0
201-300	5	0	3	0	3	0	6	0	0	0	1	0	3	0	4	0	25	0
301-400	7	0	2	0	3	0	4	0	2	0	1	0	8	0	1	0	28	0
401-500	5	0	7	14	2	67	6	50	0	-	1	0	7	29	3	0	31	23
501-600	7	0	4	50	2	100	9	88	0	-	2	50	11	33	5	40	40	45
601-700	10	45	7	83	1	100	0	-	0	-	0	-	5	100	3	100	26	75
701-800	7	86	0	-	1	100	0	-	4	100	0	-	1	100	1	100	14	88
Nb occurrences		11		10		5		9		4		3		12		6		60
Nb samples		65		37		18		67		33		65		86		18		389
Min depth sampled		41		43		37		40		41		27		25		124		25
Max depth sampled		786		660		720		586		780		579		703		750		786
Min depth occurrence		609		454		427		415		735		579		414		590		
Max depth occurrence		780		658		723		586		785		579		703		750		

nb = number of samples. S1-WALB = northwestern Alborán Sea; S2-EAL = northeastern Alborán Sea; S3-VERA = Gulf of Vera; S4-VALE = Valencia zone; S6-DELT = Ebro Delta zone; S7-NCAT = northern Catalonian zone; S8-EIVI = Eivissa Channel.

The mean percentage of occurrence was 23% from 414 m to 480 m depth, 47% from 506 m to 600 m, 75% from 609 m to 693 m and 88% from 703 m to 786 metres.

The dendrogram of similarities among size distribution samples is shown in figure 2. The characteristics of these assemblages are summarized in table 2 and figure 3.

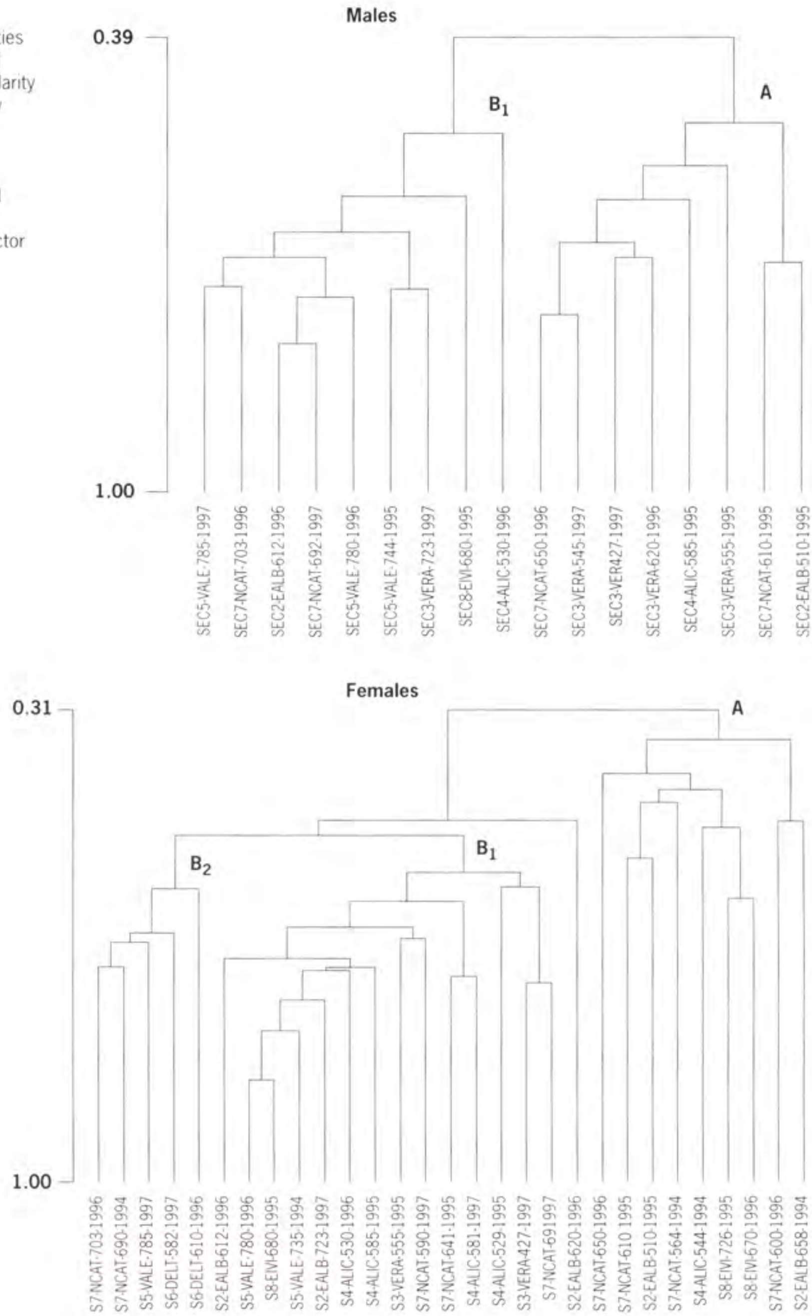


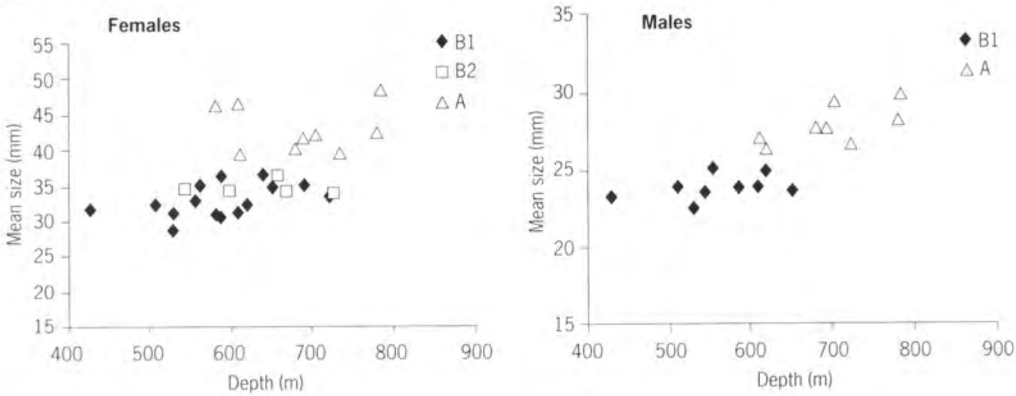
Figure 2
Dendrogram of similarities among samples, based on the percentage similarity between size frequency distributions for males and females of *A. antennatus*. Each sample is labelled with the code of the geographical sector and depth.

Table 2 - Characteristics of the sample assemblages identified through clustering methods based on the resemblance between size frequency distributions.

	Median depth (m)	Mean depth (m)	SEM	Nb	Mean size	Modal size	Min. depth	Max. depth
Males								
A	713	714.88	56.74	8	27.85	26.87 33.09	612	785
B1	555	559.11	67.23	9	23.88	23.51 29.41 32.63	427	650
Females								
A	690	686.33	73.69	9	43.09	24.20 30.48 40.30 49.15	582	785
B1	583	577.43	66.79	14	32.90	29.14 37.49 49.95	427	723
B2	658	639.60	69.71	5	34.65	34.37 43.87	544	726

SEM = standard error of the mean; Nb = number of samples per assemblage.

Figure 3
Relationship between mean size and depth of samples of *A. antennatus* for the clustering groups performed.



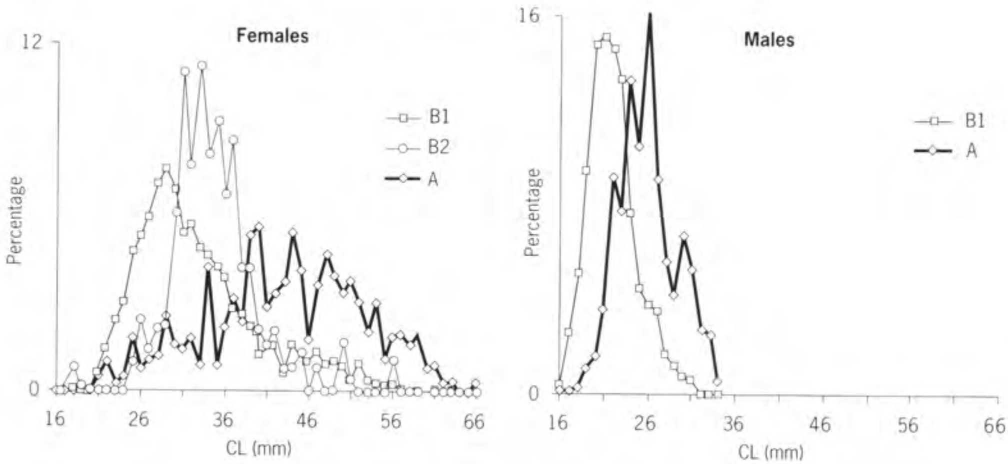
Assemblage A was performed for a high proportion of females larger than 40 mm CL and males larger than 24 mm CL. The most important modal size classes in this assemblage were 40 mm and 49 mm CL for females and 27 mm CL for males. Large specimens were found together with young specimens (16-25 mm CL), although the proportion of such occurrences was not very high. The samples that contributed most to this assemblage were the deepest ones from sectors 2, 5 and 7.

In assemblage B1, the most important modal components were 29 mm CL for females and 24 mm CL for males. The samples of this assemblage corresponded to the shallowest depths of occurrence in sectors 2 and 7, with most coming from sectors 3 and 4, from 400 m to 550 m depth.

Assemblage B2 was composed only of females, and the main modal class was 34 mm CL. The samples in this group corresponded to intermediate depths (sectors 2 to 7) and all of those collected in sector 8 (at around 550-650 m depth).

A pooled size frequency distribution was constructed for each of the main groups (fig. 4). The sizes ranged between 16 and 66 mm CL for females and 16 and 36 mm CL for males.

Figure 4
Pooled size frequency distributions of *A. antennatus* for the assemblages obtained by the clustering method.



The yields in number and weight by sector, depth and year are shown in table 3. The species was scarce in sector 1, and the specimens caught were mostly of larger size. The highest yields were from sector 7 (showing a wide bathymetric range of occurrence: 414 m to 700 m depth), followed by sector 2 (454 m to 723 m) and sector 5 (characterized by the deepest range: 735 m to 785 m). In all cases, mean yields were over four kilogrammes per hour. The Gulf of Vera, Alicante zone (415 m to 620 m), the Eivissa Channel (585 m to 754 m), and the Ebro Delta zone (530 m to 610 m) had similar yields of between one and two kilogrammes per hour.

Discussion

The depth range of the surveys enabled us to determine the upper limit of the bathymetric distribution of *A. antennatus*. However, this range did not cover all of the bathymetric distribution since this species can be found at over 2,000 m depth (Cartes & Sardà, 1992). The abundance of samples was greater from 500 m to 700 metres. The depth range covered by the survey clearly shows where the greatest abundance can be found within the bathymetric range of commercial trawl-fishing.

Size frequency distribution showed increasing mean size for both females and males at deeper stations and a distribution of small individuals at all depth ranges. Sardà & Cartes (1997), however, noted the recruitment of early juveniles on the lower slope in winter in the northern Catalonian zone. The size frequency distributions for our samples were more similar with respect to depth and geographic sector.

The size distributions were in fact quite similar to those obtained for commercial vessels in the same areas (Demestre *et al.*, 1993a, b; Carbonell, 1994; Martínez Baños, 1994). As the net used during the trawl survey (20 mm stretched mesh size) was smaller than that used by commercial vessels (around 40 mm mesh size), the presence of juveniles could have been more related to the period of the year and the depth.

When all the sectors are taken into account, three main distribution areas are apparent: a first one comprising the northeastern Alborán Sea and the Gulf of Vera (sectors 2 and 3), a second formed by the Eivissa Channel (sectors 4, 5 and 8) and a third corresponding to the Catalonian area (sectors 6 and 7).

Table 3 - Mean abundance (in number and grammes per hour) of *A. antennatus* as a function of depth stratum and geographical sector.

	S 1		S 2		S 3		S 4		S 5		S 6		S 7		S 8	
	Nb/h	g/h	Nb/h	g/h	Nb/h	g/h	Nb/h	g/h	Nb/h	g/h	Nb/h	g/h	Nb/h	g/h	Nb/h	g/h
MEDITS 1994																
400-500 m	0	0	0	0	0	0	0	0	0	0	0	0	8	113	0	0
501-600 m	0	0	1	18	0	0	11	152	0	0	0	0	38	575	0	0
601-700 m	0	0	26	401	0	0	0	0	0	0	0	0	48	933	0	0
701-800 m	0	0	0	0	0	0	0	0	25	505	0	0	0	0	0	0
MEDITS 1995																
400-500 m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
501-600 m	0	0	157	2126	74	828	67	748	0	0	0	0	0	0	5	137
601-700 m	0	0	0	0	0	0	0	0	0	0	0	0	169	2230	41	858
701-800 m	10	177	0	0	0	0	0	0	35	575	0	0	0	0	55	705
MEDITS 1996																
400-500 m	0	0	0	0	9	130	2	32	0	0	0	0	0	0	0	0
501-600 m	0	0	0	0	0	0	56	565	0	0	0	0	23	542	0	0
601-700 m	3	55	35	646	0	0	0	0	0	0	0	0	159	2545	31	435
701-800 m	2	41	0	0	0	0	0	0	167	3198	0	0	87	1811	0	0
MEDITS 1997																
400-500 m	0	0	2	40	190	2117	2	22	0	0	0	0	0	0	14	236
501-600 m	0	0	0	0	47	383	99	1151	0	0	14	383	53	966	22	402
601-700 m	1	18	13	204	0	0	0	0	0	0	0	0	117	1839	0	0
701-800 m	2	53	0	0	151	1614	0	0	90	1990	0	0	0	0	0	0

S1 = northwestern Alborán Sea; S2 = northeastern Alborán Sea; S3 = Gulf of Vera; S4 = Alicante zone; S5 = Valencia zone; S6 = Ebro Delta zone; S7 = northern Catalonian zone; S8 = Eivissa Channel.

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Acknowledgements

We wish to thank all participants in the MEDITS-ES cruises on board the R/V *Cornide de Saavedra* for their assistance and support.

Spatio-temporal distribution of *Aristeus antennatus* (Risso, 1816) (Crustacea: Decapoda) in the northwestern Ionian Sea: preliminary data using geostatistics

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Abstract

The spatio-temporal distribution of the blue and red shrimp *Aristeus antennatus* (Risso, 1816) in the Ionian Sea was analyzed using geostatistical techniques. Data were collected during November 1994 and May 1995 as part of a European Union study project. The variables investigated were the "abundance index" (kg/km^2) and the "percentage of females larger than median length". The spatial structure of each variable was described by the auto-variogram function, while the cross-variogram was used to analyse the spatial structure of the "abundance index", sampled in two different surveys, in order to detect the persistence of spatial continuity over time. The ordinary kriging technique was applied to estimate the spatial distribution of both variables. In addition, the co-kriging method allowed estimation of the "abundance index" in the spatio-temporal dimension. Zones in which there was a higher conditioned probability of finding females larger than median length were estimated by the disjunctive kriging technique.

Although our results can be considered as preliminary, they show spatial continuity, described by an exponential variogram model, within high fluctuations in abundance between the two surveys. The abundance maps indicate that *A. antennatus* was mainly distributed in two areas of the Ionian basin: within the Gallipoli fishery (northwards) and along the Calabrian coast (southwards). The kriging map, representing the distribution pattern of the size structure of females, showed a latitudinal gradient of increasing size structure for *A. antennatus* stock from the southernmost towards the northernmost area. Moreover, the map of the conditioned probability distribution of the size structure of females allowed the localisation of a zone in the northernmost area with the highest probability of containing more than 50% of females larger than median length.

Introduction

The biology of the blue and red shrimp *Aristeus antennatus* (Risso, 1816), a species of considerable interest in the Ionian Sea, has been largely documented within the last decade (*e.g.* Matarrese *et al.*, 1992, 1997; Tursi *et al.*, 1993; D'Onghia *et al.*, 1997), but its spatio-temporal distribution in this mid-eastern Mediterranean basin is still not clearly known. Bottom geomorphology and the fishing pattern have been considered as important factors in determining the latitudinal gradient in abundance fluctuations and size structure on a short spatio-temporal scale (D'Onghia *et al.*, 1998). Such a gradient was identified through a simple, statistically tested comparison of catch and length-frequency data between depths and geographic zones (*op.cit.*). Nevertheless, an analysis explicitly accounting for spatial considerations, such as that provided by geostatistics (Matheron, 1965), can contribute to a more thorough analysis and estimation of the distribution pattern of this resource. In fact, the kriging estimation techniques of linear geostatistics have been widely applied to trawl survey data (Anon., 1990; Lembo *et al.*, 1990; Fariña *et al.*, 1994; Maynou *et al.*, 1996). The advantage of this approach consists in the possibility of operating without restrictions on the probability distribution function. Thus, the value of a given variable is estimated taking into account its spatial structure as described by the variogram model. At the same time, the shape and extent of the investigated area, as well as the geometry of the data configuration, are considered in the analysis (Matheron, 1965; Journel & Huijbregts, 1978). Among kriging techniques, co-kriging allows a given variable to be estimated when data on the spatio-temporal correlation provided by the cross-variogram model are also taken into account (Myers, 1982, 1988; Rouhani & Myers, 1990). The application of this technique to trawl survey data improved estimates of abundance indices for the European hake *Merluccius merluccius* when information was used concerning the persistence of the spatial structure over time (Lembo *et al.*, 1998a). Furthermore, localisation and spatial delimitation of some biometric characteristics of a given species, such as size, can be a desirable objective in studying the distribution of fishery resources. In this case, the disjunctive kriging technique of non-linear geostatistics can be considered as a useful tool, allowing an estimation of the conditioned probability of exceeding a given threshold value of the variable under investigation (Yates & Warwick, 1986; Rivoirard, 1994). The purpose of the present study was to use geostatistical analysis to provide preliminary results on the spatio-temporal distribution of A. *antennatus* in the Ionian Sea.

Materials and methods

The overall study area, between Cape S. Maria of Leuca (Lecce, Italy) and Roccella Ionica (Catanzaro, Italy) (fig. 1), concerns a total surface area of about 3,400 km^2 and depths between 350 and 750 metres.

Data were collected during November 1994 and May 1995 as part of the EC study project MED 92/015 (Tursi *et al.*, 1996).
A commercial 75-ton (gross tonnage) vessel with a 360 Hp engine was chartered. It was equipped with a nylon otter-trawl net with a 40 mm stretched mesh (20 mm side) in the codend. Horizontal and vertical net openings measured for each depth by means of the Scanmar sonar system (Fiorentini *et al.*, 1994) depended on various factors (depth, warp length, towing speed, etc.) and ranged from 21.71 to 25.09 m and from 0.8 to 0.73 m respectively. Vessel speed, as measured by GPS, was maintained at 2.5-2.8 knots.
A stratified-random sampling design was adopted (Fogarty, 1985). A total of 15 and 16 hauls was carried out during November 1994 and May 1995 respectively (fig. 1). Fishing was restricted to daylight hours, and hauls lasted two hours each on average.

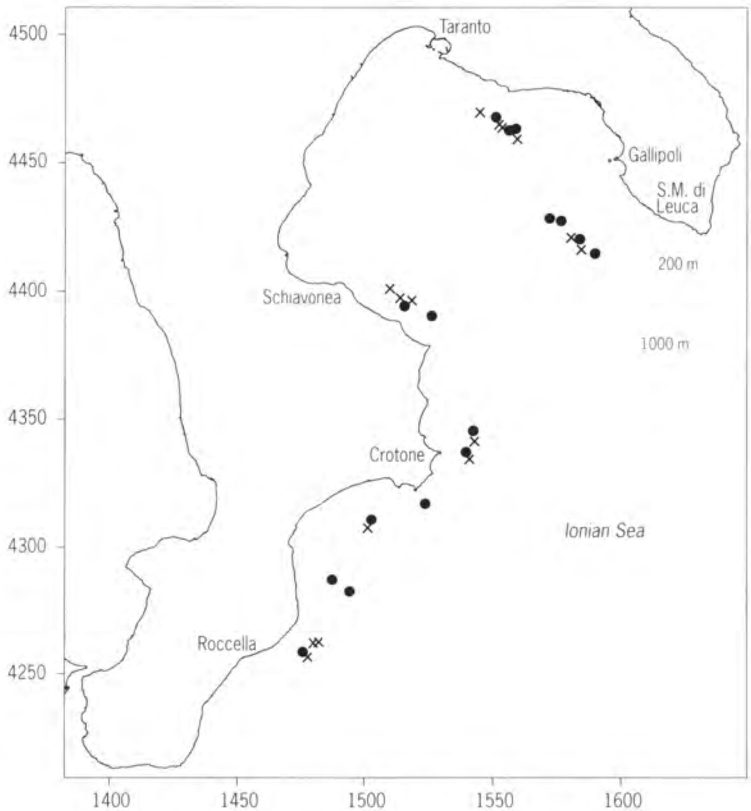


Figure 1
Study area with localisation of hauls carried out in November 1994 (X) and May 1995 (•) surveys. The geographical co-ordinates on the axis are expressed in the linear system (km).

For each specimen of *A. antennatus*, carapace length (CL) was measured to the nearest millimetre, from behind the orbit of the eye to the posterior border of the cephalothorax (Orsi Relini & Relini, 1979). Length-frequency distributions of *A. antennatus* females were determined by survey. Considering the multimodal trend exhibited in each of them, median length was estimated and used to check differences in the size structure of the stock. The total number and weight of *A. antennatus* caught in each tow were measured. The weight of *A. antennatus* for each haul-swept area was then computed as an abundance index (kg/km^2). The "swept area" was estimated according to the wingspread of the net and the speed of the vessel (Pauly, 1983). The former changed with the length of warp, which in turn depended on the depth of the haul (Fiorentini *et al.*, 1994).

The spatially correlated variables under investigation were the "abundance index" (kg/km^2) and the "percentage of females larger than median length" (%). For the latter variable, only females were considered because they reach a larger size than males (Matarrese *et al.*, 1997). The spatial structure of each above-mentioned variable was described by the auto-variogram function. The cross-variogram function was used to describe the spatial correlation of the abundance index measured in two different surveys, in order to detect the presence of a temporal persistence of the spatial structure.

The variogram estimator (auto- or cross-) used (Journel & Huijbregts, 1978) was:

$$\gamma^*_{ij}(h) = \frac{1}{2n(h)} \sum_{k=1}^{n(h)} (z_i(x_k + h) - z_i(x_k))(z_j(x_k + h) - z_j(x_k))$$

where $z_i(x_k)$ and $z_i(x_k+h)$ are the experimental values of the variable Z_i "abundance index" or "percentage of female larger than median length" at time t_i in the location x_k and (x_k+h), for the auto-variogram (in this case, $i = j$ and the increments are squared); $z_i(x_k)$, $z_i(x_k+h)$ and $z_j(x_k)$, $z_j(x_k+h)$ are the experimental values of the variable "abundance index" Z_i and Z_j at time t_i and t_j in the location x_k and (x_k+h), for the cross-variogram; and $n(h)$ is the number of distinct pairs of points separated by the vector h. A valid variogram model was fitted to each experimental variogram, adapting the most common type of theoretical models: spherical, exponential and Gaussian. The first two models describe a good level of spatial continuity, while the third is suitable for modelling highly continuous phenomena (Matheron, 1971; Journel & Huijbregts, 1978). Thus, the spherical and exponential models were expected to be more relevant for a spatial process such as the distribution of the abundance of a demersal resource. The parameters of the variogram models were estimated. The nugget indicates a microscale variability or measurement error, the range is the distance beyond which the variable values at two points become uncorrelated, and the sill is the variability value at which the variogram reaches the plateau (Journel & Huijbregts, 1978). For each variogram, the anisotropic behaviour of the variable was studied in order to fit the model to the four spatial orientations: north, south, east, and west. The variogram models were cross-validated by jackknife methods (Miller, 1974).

In order to apply estimation kriging techniques, a grid was drawn on the investigated area. The mesh size of the grid, which can be made more

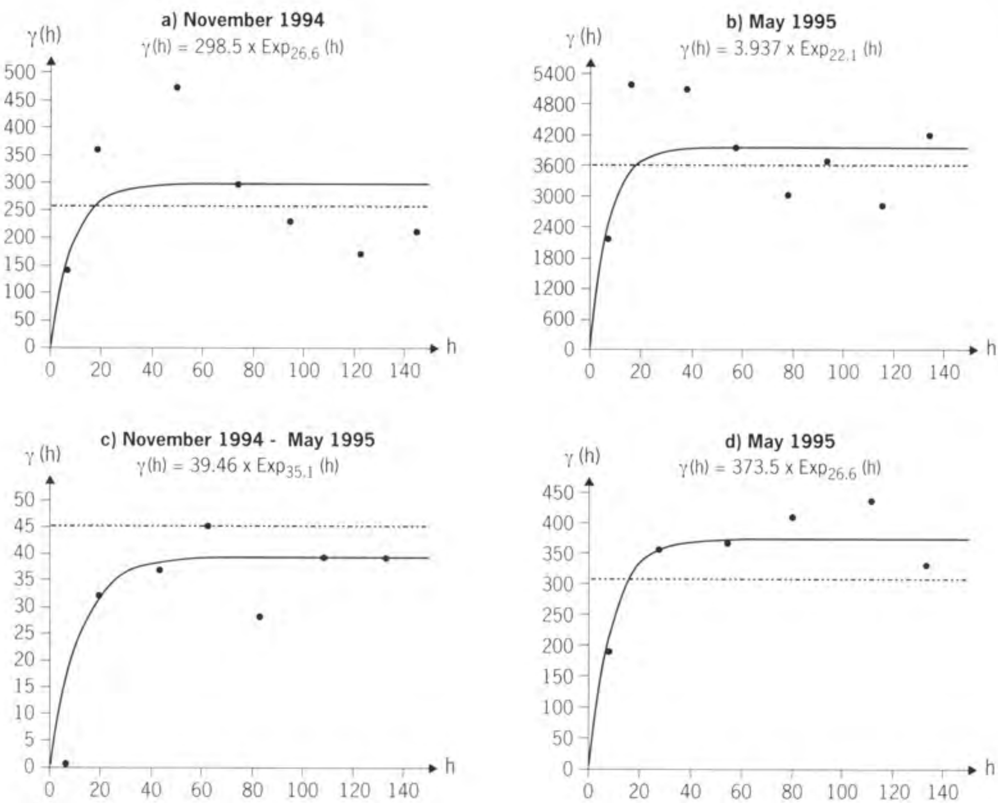
or less wide according to the required level of sensitivity, measured one kilometre in our case. At each grid crossing point, the estimate of the "abundance index" was performed by ordinary kriging and co-kriging methods (Journel & Huijbregts, 1978; Isaaks & Srivastava, 1989), while the estimation of the "percentage of females larger than median length" was obtained only by ordinary kriging. The advantage of the kriging technique is to provide a minimum variance unbiased linear estimator. Moreover, when two or more variables are correlated, the co-kriging technique can be used to estimate any variable from the data available on all the correlated ones. Thus, the co-kriging method was applied, relative to the spatio-temporal correlation (Myers, 1982, 1988; Rouhani & Myers, 1990) of the "abundance index" observed in two different surveys (November 1994 and May 1995), allowing the estimate of the studied variable to be improved by cross-correlation (Isaaks & Srivastava, 1989). The same grid crossing points used for assessing the value of the "abundance index" and the "percentage of females larger than median length" served to determine the estimation variance (Journel & Huijbregts, 1978). The kriging variance, which can be explained in terms of the confidence level to be set on the estimates achieved in the prediction process, depended only on the structural model and not on the experimental data.
The disjunctive kriging technique of non-linear geostatistics, which provides a non-linear kriging estimator (Journel & Huijbregts, 1978; Yates & Warwick, 1986; Rivoirard, 1994), was applied to predict the conditioned probability of exceeding a given threshold value of the variable "percentage of females larger than median length". For this prediction process, a cut-off value of 50% was chosen and the length data for May 1995 were used since more individuals were recorded in samples from that survey.

Results

During the two surveys, a total of 7,662 individuals of *A. antennatus* were caught in the study area across the whole depth range investigated. The total number of females was 5,674 (4,487 in the survey of May 1995), with a carapace length of 13 mm to 68 millimetres. Considerable changes in abundance were observed, ranging from zero values to more than 200 kg/km^2 (survey of May 1995).
Structural analysis allowed us to estimate the model and variogram parameters, which showed spatial continuity, with a geometric anisotropy ratio of 2 and an angle of 110 degrees. This anisotropic behaviour seemed to be related to the morphology and the bathymetric profile in much of the study area, as well as to the distribution pattern of the species. In this preliminary phase of the geostatistical study in the investigated area, the experimental variograms were better fitted by an exponential model. The auto-variogram models of November 1994 and May 1995 (fig. 2) for the variable "abundance index" showed spatial

continuity, with ranges of 26.6 km and 22.1 km respectively. Sill values were 298.5 $(kg/km^2)^2$ and 3,937 $(kg/km^2)^2$. The temporal persistence of spatial continuity through two different seasons (November 1994 and May 1995) was detected by the cross-variogram (fig. 2). In this case, an exponential model was also fitted, with a range of 35.1 km and a sill of 39.46 $(kg/km^2)^2$. Thus, the cross-correlation analysis contributed to increasing the spatial continuity range and reducing variability. As in the previous cases, the auto-variogram of the variable concerning the "percentage of females larger than median length", which was also performed with the data of May 1995 (fig. 2), was fitted by an exponential model with a spatial continuity range of 26.6 km and a sill value of 373.5 $(\%)^2$.

Figure 2
Experimental and variogram models [$\gamma(h)$] of the abundance index (kg/km^2) (a, b, c) and the percentage number of females larger than median length (d). Distance h in km.



The kriging estimation of the abundance index for the survey of November 1994 (fig. 3) allowed the delimitation of three main areas characterized by a greater abundance of *A. antennatus*. Two were located along the Calabrian coast (Crotone fishery) and one along the Apulian coast (Gallipoli fishery). The maximum estimated abundance index (56 kg/km^2) was in the Crotone fishery.

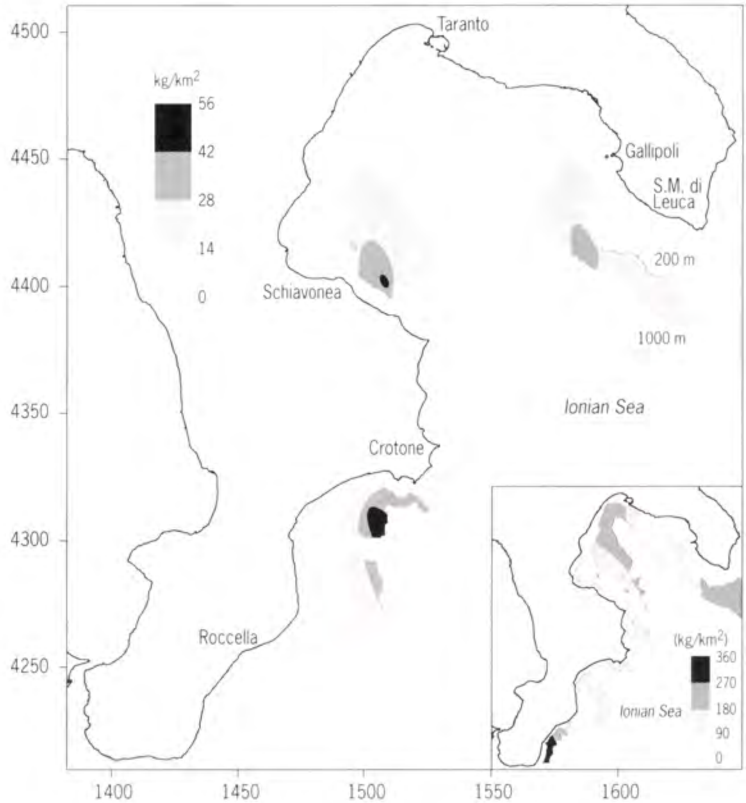


Figure 3
Kriging estimation of the abundance index (kg/km^2) of *Aristeus antennatus*. Survey of November 1994. Kriging estimation variance in the window. The geographical co-ordinates on the axis are expressed in the linear system (km).

The co-kriging estimation for the survey of May 1995 (fig. 4) indicated a very high abundance of *A. antennatus* in the Gallipoli area and along the Calabrian coast between Crotone and Roccella. The catches obtained in this survey were much more abundant (up to 220 kg/km^2) than those of November 1994. For both kriging and co-kriging, the maps of estimation variance, reported in the windows of figures 3 and 4, showed the localisation of lower levels of variability corresponding to the highest abundance values. Thus, these areas can be considered as characterized by a more reliable confidence level for the estimates.

With regard to the size structure of *A. antennatus* females in the study area, the map obtained by kriging estimation (fig. 5), in consideration of the distribution of the "percentage of females larger than median length", revealed a latitudinal gradient of increasing size from the southernmost investigated area northwards. The lowest and highest percentages of larger females were found in the Roccella and Gallipoli zones respectively. In this case, the lower estimation variance values corresponded to the higher percentage of larger females (window in fig. 5). In addition, the spatial distribution pattern of the size structure of *A. antennatus* females was analyzed by applying disjunctive kriging techniques, allowing the map of the conditioned probability distribution

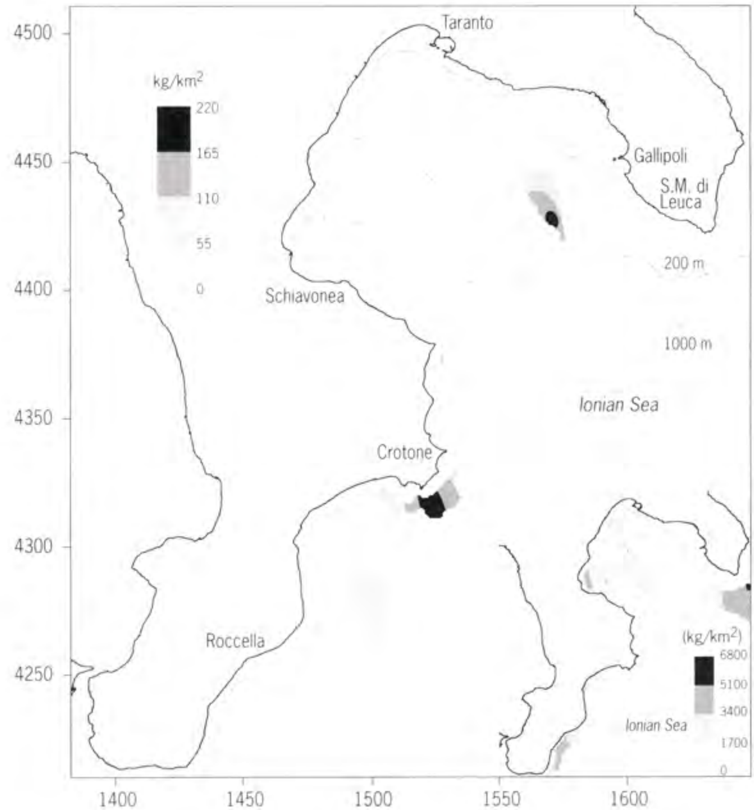


Figure 4
Co-kriging estimation of the abundance index (kg/km²) of *Aristeus antennatus*. Survey of May 1995. Co-kriging estimation variance in the window. The geographical co-ordinates on the axis are expressed in the linear system (km).

of the "percentage of females larger than median length" to be plotted (fig. 6). This map was created taking as threshold value the percentage equal to or higher than 50% of the females whose size was larger than median length. The geographic representation of this result also showed a latitudinal gradient of the size structure of *A. antennatus* stock in May 1995, with the highest conditioned probability (0.56) of finding larger specimens in the northernmost area (Gallipoli fishery).

Discussion and conclusions

Aristeus antennatus is a resource exhibiting high fluctuations in abundance throughout the Mediterranean basin (*e.g.* Relini & Orsi Relini, 1987; Orsi Relini & Relini, 1988; Sardà, 1993; Sardà *et al.*, 1994). Generally, these fluctuations are correlated with seasonal migrations of the species (Sardà, 1993; Sardà *et al.*, 1994; Maynou *et al.*, 1996). Although the results presented in this paper indicate such variations in the Ionian Sea, they show that two main areas, characterized by higher abundance levels, can be localized. At the current preliminary stage of geostatistical analysis in the investigated area, the spatial structure of the "abundance index" seems to be described by an exponential

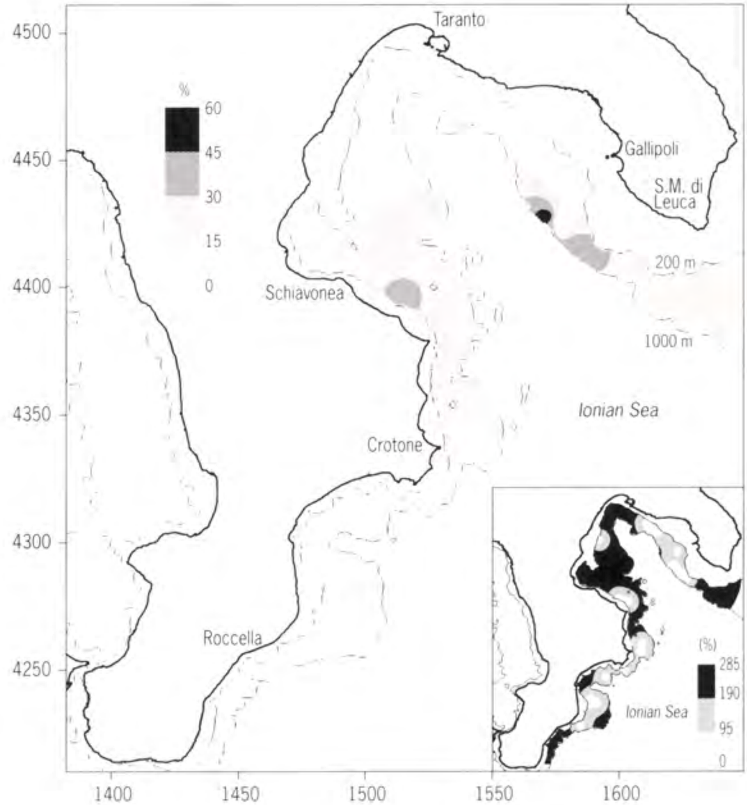
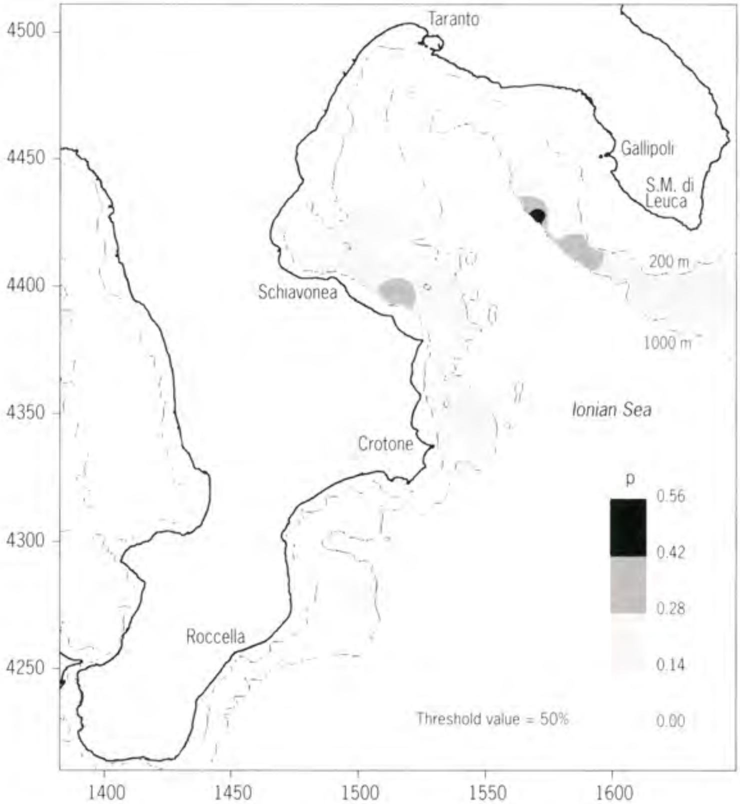


Figure 5
Distribution of the percentage of *Aristeus antennatus* females larger than median length, by kriging estimation. Survey of May 1995. Kriging estimation variance in the window. The geographical co-ordinates on the axis are expressed in the linear system (km).

model, whose ranges indicate a spatial continuity characterized by a rather long radius. Such spatial continuity showed a similar magnitude between surveys and seasons, irrespective of the observed fluctuations in abundance. A comparable spatial structure of the "abundance index" was also observed in the analysis of MEDITS survey data (summer of 1994 and 1995) (Bertrand *et al.*, 2000), which resulted in an exponential model with range values of 20.4 km and 20.8 km respectively (unpublished data). Analysis of the cross-correlation of the "abundance index" for two seasons allowed an estimation of increased spatial continuity, with a longer radius than that evaluated by auto-variograms. Moreover, the spatio-temporal cross-correlation contributed to a remarkable decrease in the cross-variogram sill, reducing the spatial variability associated with "abundance index" estimates. Although based on preliminary evaluations, the co-kriging prediction process enabled us to detect a persistent localisation of higher abundance indices in certain zones (Gallipoli area and along the Calabrian coast between Crotone and Roccella) throughout the surveys. This estimation method has already been applied effectively to another Mediterranean area, allowing the distribution of *Merluccius merluccius* abundance to be studied through different seasons (Lembo *et al.*, 1998a) and improving the reliability of the estimates.

Figure 6
Conditioned probability distribution of the percentage of *Aristeus antennatus* females larger than median length, by disjunctive kriging estimation. Survey of May 1995. The geographical co-ordinates on the axis are expressed in the linear system (km).



Concerning the spatial structure of the variable "percentage of females larger than median length", a continuity range comparable to those observed for the "abundance index" was found. For this variable, two main areas characterized by a higher percentage of larger females were also localised by the kriging estimation process. In addition, the disjunctive kriging prediction allowed delimitation of zones in which the conditioned probability of finding more than 50% of females larger than median length was higher. This estimation process appeared to be a useful approach for investigating the spatial localisation of the size structure pattern of *A. antennatus* females, as observed in delimiting nursery areas of *Merluccius merluccius* (Lembo *et al.*, 1998b). The very selective threshold value (50%) chosen for the analysis enabled us to determine that the size structure pattern of *A. antennatus* in the Ionian Sea showed a latitudinal gradient of carapace length. A significant increase in the "percentage of females larger than median length" was observed from the southernmost zone northwards, particularly in the Gallipoli fishery where the conditioned probability of finding very large females was as high as 0.56.

Differences in size-structure patterns among the areas, as reported in D'Onghia *et al.* (1998), could be related to various factors. One concerns the effects of the difference in fishing pressure, which is higher along the Calabrian coast than in the Gallipoli fishery. In the former, fishing occurs all day long throughout the week, whereas in the latter it is limited to daylight hours from Monday to Friday. Moreover, the trawlers in the Crotone fishery have a greater capacity than those of Gallipoli. Another possible explanation for differences in the size structure pattern in spatial terms is the geomorphology of the continental slope, particularly the existence of canyons in the southernmost area which could prevent complete coverage of the stock by fishing gear (Sardà *et al.*, 1994; D'Onghia *et al.*, 1997, 1998). The lower proportion of large females in the stock sampled in this zone could also result from size-dependent migration into areas unsuitable for trawling. If this is confirmed in future studies, it might imply that the vulnerability of *A. antennatus* spawners in the Roccella area is lower than in the Gallipoli area. The greater availability of ecological refuges (*i.e.* canyons) for spawners might ensure more successful recruitment in the Roccella area. Furthermore, the higher density of small specimens found in the southernmost zone might also be related to the displacement of a fraction of the larvae as a result of cyclonic circulation (even on the bottom) of the water mass in the Gulf of Taranto (Gasparini & Griffa, 1986).

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Bathymetric and geographical variability in the characteristics of a population of *Nephrops norvegicus* (Crustacea: Decapoda) off the Iberian peninsula (western Mediterranean)

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Abstract

The patterns of occurrence and size structure of *Nephrops norvegicus* obtained off the Mediterranean coasts of the Iberian Peninsula were analyzed as a function of depth and geographical sector. Three hundred and eighty-nine hauls were taken at depths of 25 to 786 m in the spring of 1994, 1995, 1996 and 1997, and 112 occurrences of *N. norvegicus* were studied. The depth range of the species was between 61 and 739 m, with strata between 300 and 500 m being most characteristic (presence in more than 80% of samples). However, *N. norvegicus* was also found in wide areas of the continental shelf, especially off the Ebro Delta. Several distinct locations showed a similar size structure. A high proportion of large individuals was found in the Alborán Sea and throughout the area at the deepest range of occurrence.

Introduction

The Norway lobster *Nephrops norvegicus*, one of the main target species along the western Mediterranean slope, has been the subject of important biological and fishery studies (Sardà, 1995, 1998; Maynou & Sardà, 1997; Maynou *et al.*, 1996). Research in other geographical areas has shown considerable heterogeneity in the spatial population structure of the species (Chapman & Howard, 1988; Tully & Hillis, 1995; Tuck *et al.*, 1997). The purpose of this paper was to analyse the depth and zonal distribution patterns of the species along the Mediterranean coast of the Iberian Peninsula as well as variability in size structure relative to depth and geographical sector.

Materials and methods

The samples studied were obtained from 389 hauls performed during daylight hours between depths of 25 and 786 m in the spring (May and June) of 1994, 1995, 1996 and 1997 on board the R/V *Cornide de Saavedra* within the context of the European Union research project MEDITS (DG XIV: MED 93/018). The surveys took place along the Iberian coasts of the Mediterranean (excluding most of the Balearic islands) from Gibraltar to Cape Creus. The bottom trawl used (2.8 m vertical opening and 20 mm codend mesh size) was towed at a speed of three knots. Depth-stratified random sampling took into account the surface area of each depth and the geographical sector interval.

For analysis of the distribution patterns, 50 m depth intervals were used down to 200 m and 100 m intervals on the slope. The area was divided into eight geographical sectors:
- western Alborán Sea;
- eastern Alborán Sea;
- Gulf of Vera;
- Alicante;
- Valencia;
- Ebro Delta;
- northern Catalonia;
- Eivissa.

One hundred and twelve occurrences of *N. norvegicus* were found in the 389 samples taken (fig. 1).

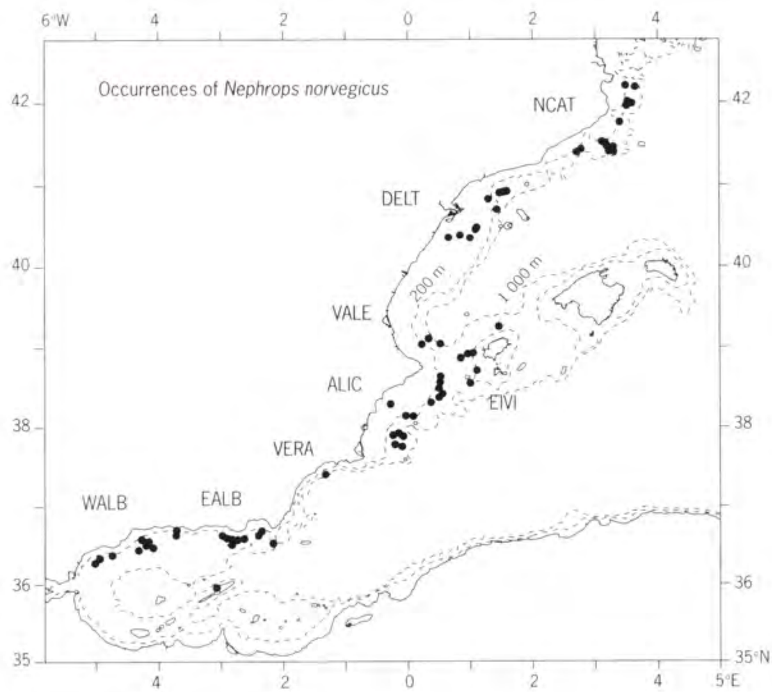


Figure 1
Occurrence of *Nephrops norvegicus* in the study area: 200 m and 1,000 m isobaths.
WALB: western Alborán sea,
EALB: eastern Alborán sea,
VERA: Gulf of Vera,
ALIC: Alicante,
VALE: Valencia,
DELT: Ebro Delta,
NCAT: northern Catalonia,
EIVI: Eivissa.

The total *Nephrops* catch was weighed, and all individuals were counted, sexed and measured [carapace length (CL) in mm]. Size frequency distributions were calculated by sex for each sample. Cluster analysis, based on the resemblance between size frequency distributions per sample, was applied using Czekanowski's percentage similarity index and the UPGMA aggregation algorithm (Abelló *et al.*, 1997). Only samples with more than twenty individuals of each sex were used to perform this analysis.

Results

Table 1 shows the percentage of occurrence as a function of depth stratum and geographical sector. *N. norvegicus* was widely distributed all along the continental slope, including areas where the shelf is wide, especially around the Ebro Delta in sectors 5 (Valencia) and 6 (Delta). The depth range for occurrence of the species was between 61 and 739 m, and strata between 300 and 500 m were most characteristic (presence of *N. norvegicus* in more than 80% of samples).

The pattern of abundance and biomass found in the different areas and depths was consistent for the four years of the study (table 2). The highest abundances were found between 300 and 500 m in most of the strata and sectors sampled, and the species was found at depths of less than 200 m only in sectors 5 and 6 (Valencia and Delta). The highest biomasses were also usually found at depths greater than 300 m (down to 600 m). Below 500 m, individuals were large but not abundant (see results below concerning the size structure of the population).

Figure 2 shows the dendrogram of similarities among samples, based on the resemblance between size frequency distributions for male and female *N. norvegicus*. The characteristics of the assemblages obtained are summarized in table 3.

Table 1 - Percentage of occurrence (% OCC) of *Nephrops norvegicus* as a function of depth stratum and geographical sector.

	SEC1-WALB		SEC2-EALB		SEC3-VERA		SEC4-ALIC		SEC5-VALE		SEC6-DELT		SEC7-NCAT		SEC8-EIVI		TOTAL		
	% OCC	Nb	% OCC	Nb	% OCC	Nb	% OCC	Nb	% OCC	Nb	% OCC	Nb	% OCC	Nb	% OCC	Nb	% OCC	OCC	Nb
0-50 m	0.0	4	0.0	3	0.0	2	0.0	8	0.0	2	0.0	12	0.0	6	--	0	0.0	0	37
50-100 m	0.0	13	0.0	6	0.0	2	0.0	21	0.0	16	13.2	38	0.0	21	--	0	4.3	5	117
100-150 m	0.0	6	0.0	3	--	0	0.0	6	11.1	9	11.1	9	0.0	20	0.0	1	3.7	2	54
150-200 m	0.0	1	0.0	2	0.0	2	0.0	7	--	0	0.0	1	25.0	4	--	0	5.9	1	17
200-300 m	40.0	5	0.0	3	0.0	3	50.0	6	--	0	0.0	1	100.0	3	50.0	4	40.0	10	25
300-400 m	85.7	7	100.0	2	0.0	3	100.0	4	100.0	2	100.0	1	100.0	8	0.0	1	82.1	23	28
400-500 m	100.0	5	100.0	7	100.0	2	100.0	6	--	0	100.0	1	100.0	7	100.0	3	100.0	31	31
500-600 m	57.1	7	75.0	4	0.0	2	100.0	9	--	0	100.0	2	100.0	11	100.0	5	85.0	34	40
600-700 m	10.0	10	28.6	7	0.0	1	--	0	--	0	--	0	20.0	5	33.3	3	19.2	5	26
700-800 m	0.0	7	--	0	0.0	1	--	0	25.0	4	--	0	0.0	1	0.0	1	7.1	1	14
Number of occurrences	18		14		2		22		4		10		31		11			112	
Number of samples	65		37		18		67		33		65		86		18				389
Min depth sampled	41		43		37		40		41		27		25		124		25		
Max depth sampled	786		660		720		586		780		579		703		750		786		
Min depth occurrence	241		336		418		258		116		61		184		214		61		
Max depth occurrence	614		627		424		586		739		579		610		672		739		

Nb = number of samples taken within each sector and depth interval; OCC = number of occurrences.

Table 2 - Mean abundance (nb/h) and biomass (g/h) of *Nephrops norvegicus* as a function of depth stratum and geographical sector per cruise.

MEDITS 94	SEC1-WALB		SEC2-EALB		SEC3-VERA		SEC4-ALIC		SEC5-VALE		SEC6-DELT		SEC7-NCAT		SEC8-EIVI	
	nb/h	g/h	nb/h	g/h	nb/h	g/h	nb/h	g/h	nb/h	g/h	nb/h	g/h	nb/h	g/h	nb/h	g/h
0-50 m	0.0	0	0.0	0	-	-	0.0	0	-	-	0.0	0	0.0	0	-	-
50-100 m	0.0	0	0.0	0	-	-	0.0	0	0.0	0	0.3	32	0.0	0	-	-
100-150 m	0.0	0	0.0	0	-	-	0.0	0	4.0	246	0.0	0	0.0	0	-	-
150-200 m	-	-	0.0	0	-	-	0.0	0	-	-	0.0	0	-	-	-	-
200-300 m	-	-	0.0	0	-	-	18.5	362	-	-	-	-	-	-	-	-
300-400 m	2.5	199	-	-	-	-	-	-	30.0	409	-	-	87.7	1855	-	-
400-500 m	1.0	85	6.3	347	-	-	26.0	492	-	-	-	-	75.5	1812	-	-
500-600 m	0.0	0	1.0	21	-	-	5.7	195	-	-	-	-	18.5	526	--	-
600-700 m	0.0	0	0.3	8	-	-	-	-	-	-	-	-	0.0	0	-	-
700-800 m	0.0	0	--	-	-	-	-	-	2.0	28	-	-	-	-	-	-
MEDITS 95																
0-50 m	0.0	0	-	-	-	-	0.0	0	0.0	0	0.0	0	0.0	0	-	-
50-100 m	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.6	107	0.0	0	-	-
100-150 m	0.0	0	0.0	0	-	-	0.0	0	0.0	0	2.0	79	0.0	0	0.0	0
150-200 m	--	--	--	--	0.0	0	0.0	0	-	-	-	-	8.0	152	-	-
200-300 m	2.0	56	0.0	0	0.0	0	0.0	0	-	-	-	-	64.0	1170	0.5	5
300-400 m	11.5	435	2.0	124	0.0	0	10.0	302	-	-	-	-	125.0	2393	0.0	0
400-500 m	13.0	1000	11.0	456	-	-	19.0	740	-	-	48.0	1105	103.5	2250	81.0	2065
500-600 m	1.5	64	1.5	133	0.0	0	21.0	1044	-	-	-	-	66.0	2102	26.7	1194
600-700 m	0.0	0	0.0	0	-	-	-	-	-	-	-	-	1.5	32	0.0	0
700-800 m	0.0	0	-	-	-	-	-	-	0.0	0	-	-	-	-	0.0	0
MEDITS 96																
0-50 m	0.0	0	0.0	0	-	-	0.0	0	0.0	0	0.0	0	0.0	0	-	-
50-100 m	0.0	0	0.0	0	-	-	0.0	0	0.0	0	0.4	51	0.0	0	-	-
100-150 m	0.0	0	-	-	-	-	0.0	0	0.0	0	0.0	0	0.0	0	-	-
150-200 m	-	-	0.0	0	-	-	0.0	0	-	-	-	-	0.0	0	-	-
200-300 m	0.0	0	0.0	0	0.0	0	0.5	16	-	-	-	-	89.0	2200	0.0	0
300-400 m	25.5	1634	9.0	394	0.0	0	20.0	700	-	-	23.0	600	122.5	2800	-	-
400-500 m	30.0	2000	4.0	600	1.0	46	47.0	2700	-	-	-	-	132.0	3000	34.0	1300
500-600 m	0.5	28	1.0	42	-	-	16.5	507	-	-	-	-	60.8	1741	9.0	293
600-700 m	0.3	39	0.0	0	0.0	0	-	-	-	-	-	-	0.0	0	1.0	23
700-800 m	0.0	0	-	-	-	-	-	-	0.0	0	-	-	0.0	0	-	-
MEDITS 97																
0-50 m	0.0	0	0.0	0	0.0	0	0.0	0	-	-	0.0	0	0.0	0	-	-
50-100 m	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	-	-
100-150 m	0.0	0	0.0	0	-	-	0.0	0	0.0	0	0.0	0	0.0	0	-	-
150-200 m	0.0	0	-	-	0.0	0	0.0	0	-	-	-	-	0.0	0	-	-
200-300 m	2.0	58	-	-	0.0	0	1.0	11	-	-	0.0	0	6.0	162	1.0	3
300-400 m	4.0	316	-	-	0.0	0	27.0	850	78.0	1900	-	-	59.0	1200	-	-
400-500 m	39.5	1267	36.5	2175	3.0	53	32.0	1046	-	-	-	-	226.5	5200	29.0	703
500-600 m	1.0	102	-	-	0.0	0	25.0	1200	-	-	21.0	700	18.5	379	20.0	900
600-700 m	0.0	0	1.0	42	-	-	-	-	-	-	-	-	0.0	0	0.0	0
700-800 m	0.0	0	-	-	0.0	0	-	-	0.0	0	-	-	-	-	-	-

Figure 2
Dendrogram of similarities among samples based on the percentage of similarity between size frequency distributions for male (a) and female (b) *Nephrops norvegicus*. Each sample is labelled with its code, geographical sector and depth.

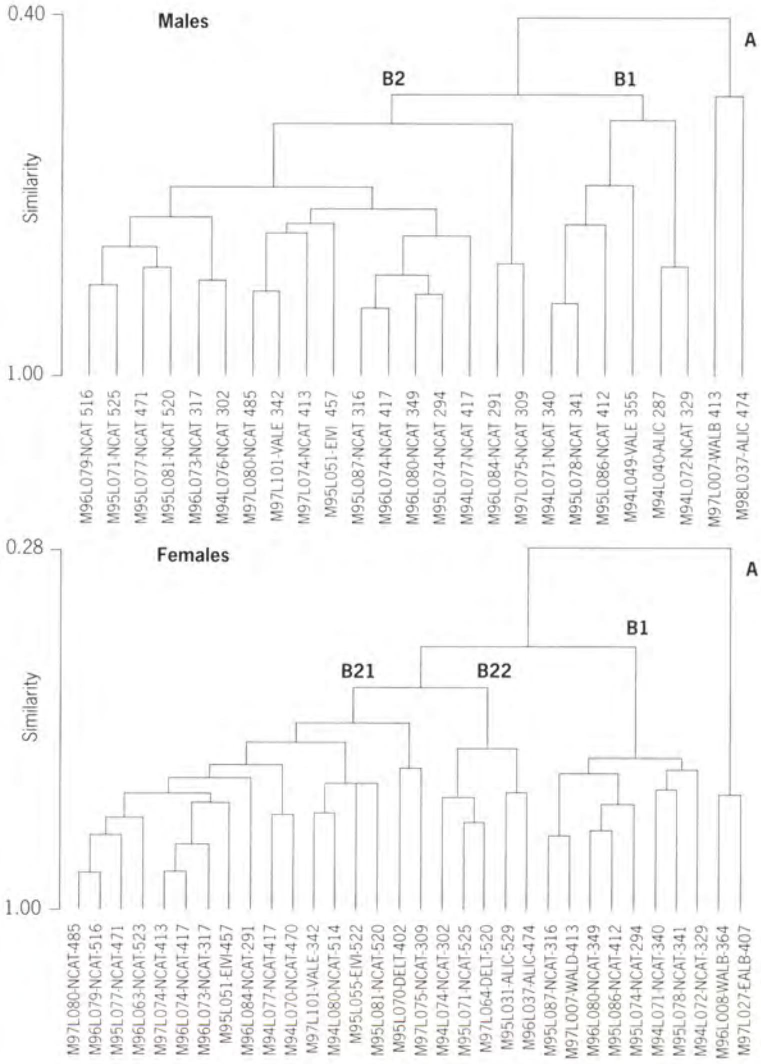


Table 3 - Characteristics of the sample assemblages identified through clustering methods by the resemblance in their size frequency distributions.

	Median depth (m)	Mean depth (m)	SEM	Nb	Mean size	Modal size class	Min. depth	Max. depth
Males								
A	443.5	443.5	30.5	2	40.7	44	413	474
B1	340.3	343.8	16.6	6	29.3	29	287	412
B2	412.5	396.3	21.1	17	33.6	35	291	525
Females								
A	386	385.5	21.5	2	41.7	41	364	407
B1	341	349.3	15.1	8	27.5	26	294	413
B21	457	434.5	19.4	17	32.2	32	291	523
B22	520	470.0	43.2	5	36.8	35	302	529

SEM = standard error of the mean; Nb = number of samples per assemblage.

A pooled size frequency distribution has been constructed for each of the main assemblages (fig. 3). Most of the samples used came from sector 7 (NCAT), which showed the highest densities in the study area.

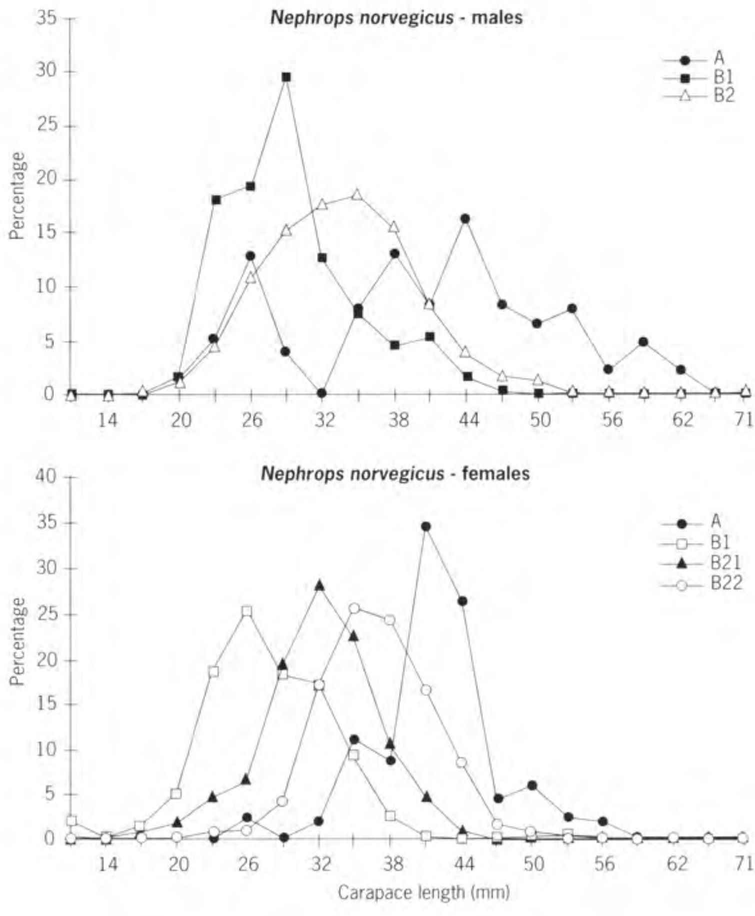
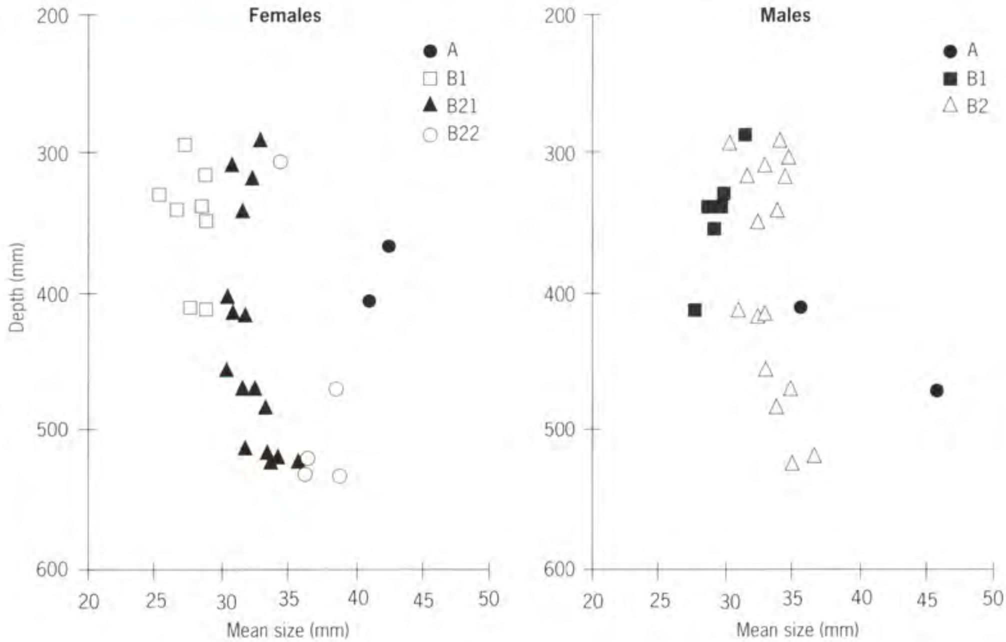


Figure 3
Pooled size frequency distributions of male and female *Nephrops norvegicus* for the main sample assemblages obtained by clustering method.

Three main clusterings of samples can be readily identified for males (A, B1 and B2). The first dichotomy separates a group of two samples (assemblage A), characterized by the occurrence of a high relative proportion of large individuals, from the rest of the samples (assemblage B). Within this group, several different subgroups can be recognized. Assemblage B1 encompasses the samples with the highest relative proportion of small individuals, whereas assemblage B2 consists mainly of those samples with a high proportion of medium-sized individuals. The relationship of the sample assemblages to depth is shown in figure 4. Thus, samples with the highest relative proportion of small individuals (assemblage B1) were found mainly between 300 and 400 m in depth, those with intermediate size classes (assemblage B2) throughout the occurrence range, and those with the highest relative proportion of large individuals (assemblage A) at greater depths of 400 m to 500 metres.

Concerning females, up to four assemblages of samples were readily discernible (A, B1, B21 and B22) (fig. 2). The first dichotomy separates a group of two samples, both from the Alborán Sea, in which large individuals dominated. Within the next dichotomy, two main groups of samples were separated: a rather homogeneous one (assemblage B1) characterized by the highest relative proportion of small individuals and another (B2) in which the proportion of small individuals was rather low and intermediate-sized individuals predominant. The highest proportion of larger individuals was found in subassemblage B22. The relationship of sample assemblages to depth and mean size (fig. 4) also indicated, as in males, that samples dominated by small individuals were found mainly within the upper range of the normal depth distribution of the species (approx. 300-400 m), whereas samples dominated by medium-sized individuals (B1) occurred throughout the depth range and those with a higher proportion of large individuals around the lower end of the distribution. The two samples constituting assemblage A were from around 400 m in depth, which would seem to be indicative of the different oceanographic characteristics of the Alborán Sea within the Mediterranean and/or of a different degree of exploitation of the species in the areas sampled.

Figure 4
Relationship between sampling depth and mean size for the samples of male and female *Nephrops norvegicus* studied. Different symbols correspond to the main groups of samples identified by cluster analysis.



Discussion

The sampling scheme enabled us to study the variability in population characteristics and distribution patterns of N. *norvegicus* on the shelf and continental slope off the Mediterranean coast of the Iberian Peninsula.

An important result of the present study was the characterization of the distribution patterns of *N. norvegicus*, both qualitatively (occurrences) and quantitatively (relative abundance). Thus, the main habitat of the species along the coasts of the western Mediterranean appears to be muddy bottoms between 300 and 500 m in depth. The occurrence of *N. norvegicus* on shelf areas in the western Mediterranean was previously reported (Abelló *et al.*, 1988; Maynou & Sardà, 1997), especially around the Ebro Delta area. However, in the Mediterranean, the continental slope constitutes the main habitat of the species (Maynou *et al.*, 1996), except in the Adriatic Sea where it also occupies the wide continental shelf (Froglia & Gramitto, 1981).

The characteristics of population structure revealed the occurrence of similarities among the samples studied, apparently related more to depths of occurrence than to the geographical area sampled. There was a tendency to find larger individuals at greater depths. Samples with a high relative proportion of large individuals were found mainly in the deepest stations, although individuals of all sizes (and especially small ones) were found throughout the depth distribution range. Similarities in the population structure of *N. norvegicus* are related to several factors, among which sediment characteristics appear to be the most important (Chapman & Howard, 1988; Tully & Hillis, 1995; Maynou & Sardà, 1997; Tuck *et al.*, 1997). Behavioural-related aspects, such as different catchability rates for each sex and size due to differential emergence rates from the burrow (Atkinson & Naylor, 1976; Hammond & Naylor, 1977; Chapman & Howard, 1979) also need to be taken into account (Chapman, 1980), although knowledge is still limited in this field. Moreover, juveniles appear to be associated with adult burrows (Chapman, 1980; Chapman & Howard, 1988). Differences in fishing effort for the various depths and areas could also have affected the population structure patterns detected. Most of the largest individuals were found in the Alborán Sea where fishing effort in *Nephrops* grounds is less developed than off the North-East Iberian Peninsula, especially for the deepest samples in the species distribution range. This may reflect both differences in fishing effort and the intrinsic characteristics of the populations, such as mobility of adults towards deeper areas and different growth rates among geographical sectors.

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Acknowledgements

We wish to thank all participants in the MEDITS-ES cruises on board the R/V *Cornide de Saavedra* for their assistance and support. We are especially grateful to Drs D. Lloris and F. Sardà (ICM, Barcelona) for their constructive comments.

Distribution of decapods caught during MEDITS surveys in Greek waters

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Abstract

This study concerns decapods caught during MEDITS96 and MEDITS97 surveys in the Ionian Sea and the region of Argosaronikos. In the Ionian Sea, a total of 29 species (14 Natantia, 11 Brachyura, 2 Macrura Reptantia and 2 Anomura) were identified in 1996, and 26 (14 Natantia, 10 Brachyura, 1 Macrura Reptantia and 1 Anomura) in 1997. In Argosaronikos, a total of 33 species (16 Natantia, 12 Brachyura, 3 Macrura Reptantia and 2 Anomura) were identified in 1996, and 40 (19 Natantia, 15 Brachyura, 4 Macrura Reptantia and 2 Anomura) in 1997. The most abundant species in the first region were, by order of importance, *Plesionika heterocarpus*, *Parapenaeus longirostris*, *Nephrops norvegicus*, *Liocarcinus depurator* and *Sergia robusta* in 1996, and *Pasiphaea sivado*, *Parapenaeus longirostris*, *Plesionika heterocarpus* and *Nephrops norvegicus* in 1997. In the second region, the most abundant species were, by order of importance, *Parapenaeus longirostris*, *Munida intermedia*, *Pasiphaea sivado*, *Plesionika heterocarpus*, *Sergia robusta*, *Munida iris rutllanti* and *Plesionika martia* in 1996, and *Parapenaeus longirostris*, *Pasiphaea sivado*, *Plesionika martia*, *Plesionika heterocarpus*, *Munida iris rutllanti* and *Sergia robusta* in 1997. A depth distribution study indicated that most shrimp species were found on the slope of both regions and most crabs on the shelf. These results are considered in relation to those obtained from surveys during other projects and for their implications for Greek fisheries, which operate at depths of less than 400 metres.

Introduction

All the information available until 1992 about the systematics and distribution of decapods of the Aegean Sea was reviewed by Koukouras *et al.* (1992). Additional information has been provided more recently in different works (Politou *et al.*, 1996; Mytilineou & Politou, 1997; Koukouras *et al.*, 1997a, b). However, the region of Argosaronikos is the most understudied area of the Aegean Sea, and the literature on the decapod fauna of Greek waters in the Ionian Sea is very limited. Some recent knowledge has been obtained in the framework of the Deep Water Fisheries project conducted by NCMR in that region.
The purpose of this study was to report the data on decapod fauna (composition, distribution and abundance) obtained during surveys in the context of the MEDITS project in the region of Argosaronikos and the Ionian

Sea. The results are considered in relation to those obtained from surveys of other projects and for their implications for Greek fisheries.

Materials and methods

Sampling was performed in the region of Argosaronikos and the Ionian Sea using a grid of 41 (19 and 22 respectively) stations in the summer of 1996 and 40 (22 and 18 respectively) in the summer of 1997. A chartered commercial trawler (length 26.3 m, two 250 HP engines) was used, equipped with sonars, DECCA RM770 and Koden radars, a geographical plotter with GPS and a Loran C and Scanmar system for observation of trawl geometry and fishing depth.
Sampling was conducted and catches analyzed according to the protocol of the MEDITS project. For non-target decapods, carapace length (CL) was measured from samples preserved in 10% formalin. Pagurids and diogenids were not analyzed because they were not collected systematically.
The abundance and biomass indices and the CPUE were calculated using the INDMED program created by A. Souplet for the MEDITS project.

Results

Global analysis

The list of species identified in the two regions is given in table 1. In the Ionian Sea, a total of 29 species (14 Natantia, 11 Brachyura, 2 Macrura Reptantia and 2 Anomura) was identified in 1996, and 26 (14 Natantia, 10 Brachyura, 1 Macrura Reptantia and 1 Anomura) in 1997.

Table 1 - List of decapod species identified in the Ionian Sea (Ion.) and the region of Argosaronikos (AS) during MEDITS-GR 96 and MEDITS-GR 97. The depth zones of their occurrence are also indicated (1: 10-50 m, 2: 50-100 m, 3: 100-200 m, 4: 200-500 m, 5: 500-800 m).

Species	Ion. 96	Ion. 97	AS 96	AS 97
Natantia				
Alpheus glaber (Olivi, 1792)		4	2, 4, 5	4
Aristaeomorpha foliacea (Risso, 1827)			4, 5	4, 5
Chlorotocus crassicornis (Costa, 1871)	4	4	4, 5	3, 4, 5
Gennadas elegans (Smith, 1882)	5	5		5
Lysmata seticauda (Risso, 1816)				3, 4, 5
Pandalina profunda Holthius, 1946	4		4	4
Parapenaeus longirostris (Lucas, 1846)	2, 3, 4	2, 4, 5	2, 3, 4	2, 3, 4, 5
Pasiphaea sivado (Risso, 1816)	4, 5	4, 5	4	4, 5
Plesionika acanthonotus (Smith, 1882)			4	4
Plesionika antigai Zariquiey Alvarez, 1955			4	
Plesionika gigliolii (Senna, 1903)	4	4		4
Plesionika heterocarpus (Costa, 1871)	4	4	3, 4	3, 4
Plesionika martia (A. Milne Edwards, 1883)	4	4	4, 5	4, 5
Plesionika narval (Fabricius, 1787)				5
Pontocaris lacazei (Gourret, 1887)	4	4, 5	4	4

Species	Ion. 96	Ion. 97	AS 96	AS 97
Natantia				
Pontophilus spinosus (Leach, 1815)	4	4	4	4, 5
Processa canaliculata Leach, 1815	4, 5	5		4, 5
Processa nouveli Al-Adhub & Williamson, 1975			4	
Sergestes sp.	5	5	4, 5	5
Sergia robusta S. I. Smith, 1882	5	4, 5	4, 5	4, 5
Solenocera membranacea (Risso, 1816)	3, 4	5	4	3, 4
Macrura Reptantia				
Calocaris macandreae Bell, 1846	2			
Jaxea nocturna Nardo, 1847			4	
Nephrops norvegicus (Linnaeus, 1758)	3, 4	4	3, 4, 5	2, 3, 4, 5
Palinurus elephas (Fabricius, 1787)				3
Polycheles typhlops Heller, 1862			5	4, 5
Upogebia pusilla (Petagna, 1792)				3
Brachyura				
Bathynectes longipes (Risso, 1816)		5		
Bathynectes maravigna (Prestandrea, 1839)	4, 5	4	5	5
Calappa granulata (Linnaeus, 1758)	1, 2			3
Dromia personata (Linnaeus, 1758)			2	
Goneplax rhomboides (Linnaeus, 1758)	1, 2, 3	2		3
Homola barbata (Fabricius, 1793)			3	3
Inachus dorsettensis (Pennant, 1777)	2	2	2	
Inachus thoracicus Roux, 1830		2	2	1, 3
Latreillia elegans Roux, 1830				3
Liocarcinus depurator (Linnaeus, 1758)	2, 3, 4	2, 3	2, 3	2, 3
Macropipus tuberculatus (Roux, 1830)	4	4	3, 5	3, 4, 5
Macropodia longipes A. Milne Edwards & Bouvier, 1899	2, 3	2, 3	2, 3	2, 3
Maja crispata Risso, 1827			1	1
Maja goltziana d'Oliveira, 1888	2			
Medorippe lanata (Linnaeus, 1767)	2, 3	2	2	
Monodaeus couchii (Couch, 1851)	5	4	3, 4, 5	3, 4
Parthenope macrochelos (Herbst, 1790)			3	3
Pilumnus spinifer H. Milne Edwards, 1834	2, 3	2, 3		1, 2
Pisa armata (Latreille, 1803)				3
Thia scutellata (Fabricius, 1793)				3
Anomura				
Munida intermedia A. Milne Edwards & Bouvier, 1899	4	4	4, 5	4
Munida iris ssp. rutllanti Zariquiey Alvarez, 1952	4		2, 3, 4	1, 3, 4

In Argosaronikos, a total of 33 species (16 Natantia, 12 Brachyura, 3 Macrura Reptantia and 2 Anomura) was identified in 1996, and 40 (19 Natantia, 15 Brachyura, 4 Macrura Reptantia and 2 Anomura) in 1997. The most abundant species caught in the Ionian Sea were, by order of importance, *Plesionika heterocarpus*, *Parapenaeus longirostris*, *Nephrops norvegicus*, *Liocarcinus depurator* and *Sergia robusta* in 1996 (table 2), and *Pasiphaea sivado*. *Parapenaeus longirostris*. *Plesionika heterocarpus* and *Nephrops norvegicus* in 1997.

Table 2 - CPUE and density indices of the most important decapods caught during MEDITS-GR 96.

Species	Ionian Sea 1996								Argosaronikos 1996							
	CPUE (NB/h)				Abundance (NB/km²)				CPUE (Nb/h)				Abundance (Nb/km²)			
	10-200 m		200-800 m		10-200 m		200-800 m		10-200 m		200-800 m		10-200 m		200-800 m	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Natantia																
Aristaeomorpha foliacea	0	0	0	0	0	0	0	0	0	0	2	53.35	0	0	22	35.30
Parapenaeus longirostris	27	70.22	121	52.34	357	86	1257	47.96	823	51.14	137	60.36	9331	50.59	1520	60.36
Pasiphaea sivado	0	0	2	65.45	0	0	22	66.72	0	0	74	37.16	0	0	827	35.10
Plesionika heterocarpus	0	0	190	75.34	0	0	1964	70.23	2	91.29	45	155.56	19	94.95	495	155.65
Plesionika martia	0	0	0	57.73	0	0	2	58.33	0	0	13	51.50	0	0	167	39.60
Sergia robusta	0	0	15	33.93	0	0	165	32.13	0	0	45	63.17	0	0	543	56.50
Sergestes sp.	0	0	10	33.56	0	0	102	34.16	0	0	2	84.67	0	0	22	99.82
Macrura Reptantia																
Nephrops norvegicus	0	91.28	16	40.75	2	87	169	43.10	5	55.14	9	70.71	61	57.25	99	70.26
Anomura																
Munida intermedia	0	0	3	74.23	0	0	33	73.80	0	0	221	56.80	0	0	2590	50.88
Munida iris rutllanti	0	0	0	99.99	0	0	1	105.18	27	79.07	7	156.34	305	76.07	73	156.44
Brachyura																
Macropodia longipes	2	50.69	0	0	30	48.78	0	0	0	81.07	0	0	3	78.31	0	0
Liocarcinus depurator	10	35.93	0	99.99	124	42.35	3	94.11	5	55.30	0	0	64	51.73	0	0

CV = coefficient of variation.

However, in terms of weight, *Nephrops norvegicus* was the most important, followed by *Parapenaeus longirostris* (both found on the slope; table 3).
In the region of Argosaronikos, the most abundant species were, by order of importance, *Parapenaeus longirostris, Munida intermedia, Pasiphaea sivado, Plesionika heterocarpus, Sergia robusta, Munida iris rutllanti* and *Plesionika martia* in 1996 (table 2), and *Parapenaeus longirostris, Pasiphaea sivado, Plesionika martia, Plesionika heterocarpus, Munida iris rutllanti* and *Sergia robusta* in 1997. In terms of weight, *Parapenaeus longirostris* was also the most important species, showing a higher biomass index on the continental shelf than on the slope (table 4).

Analysis per depth zone

Ionian Sea

The catch of decapods was very poor or inexistent in the 10-50 m depth zone, and poor (30 ind./h in 1996 and 9 ind./h in 1997) in the 50-100 m zone. *Liocarcinus depurator* accounted for 50% of the total decapod catch in 1996 and 56% in 1997. Other species found in both years were *Parapenaeus longirostris* and *Macropodia longipes*.
The catch was relatively higher in the 100-200 m zone (109 ind./h in 1996 and 57 ind./h in 1997). *Parapenaeus longirostris* composed 82% and *Liocarcinus depurator* 11% of the decapod catch in 1996, and *Liocarcinus depurator* 60% and *Macropodia longipes* 39% in 1997.
The 200-500 m zone showed the highest catch in both years (748 ind./h in 1996 and 703 ind./h in 1997). The most abundant species were *Plesionika heterocarpus* (56%), *Parapenaeus longirostris* (36%) and *Nephrops norvegicus* (5%) in 1996, and *Pasiphaea sivado* (33%), *Plesionika heterocarpus* (27%), *Parapenaeus longirostris* (26%) and *Nephrops norvegicus* (8%) in 1997.
The catch decreased in the 500-800 m zone (54 ind./h in 1996 and 75 ind./h in 1997). Sergestids comprised 83% and *Gennadas elegans* 11% of the decapod catch in 1996, and Sergestids 41%, *Pasiphaea sivado* 33% and *Gennadas elegans* 12% in 1997.
An analysis by categories showed that all shrimps were found on the slope, but that only *Parapenaeus longirostris* and occasionally *Solenocera membranacea* were fished in low quantities on the shelf (tables 1, 2 and 3). Similarly, anomurans and *Nephrops norvegicus* (in its majority) were found on the slope, whereas most of the crabs were fished on the shelf (their highest abundance indices).

Region of Argosaronikos

In the shallowest zone (10-50 m), the decapod catch was almost inexistent, as in the Ionian Sea.
In the 50-100 m zone, the catch was 67 ind./h in 1996 and 145 ind./h in 1997. The main species were *Liocarcinus depurator* (73% in 1996 and 76% in 1997) and *Parapenaeus longirostris* (18% for both years).

Table 3 - CPUE and density indices of the most important decapods caught in the Ionian Sea during MEDITS-GR 97.

Species	Ionian Sea 1997															
	CPUE (Nb/h)				CPUE (kg/h)				Abundance (Nb/km^2)				Biomass (kg/km^2)			
	10-200 m		200-800 m		10-200 m		200-800 m		10-200 m		200-800 m		10-200 m		200-800 m	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Natantia																
Aristaeomorpha foliacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parapenaeus longirostris	1	70.22	85	57.19	0.01	68.74	0.75	29.16	6	72.89	1102	53.49	0.06	71.35	9.77	28.28
Pasiphaea sivado	0	0	119	89.65	0	0	0.14	89.14	0	0	1601	86.36	0	0	1.84	85.81
Plesionika heterocarpus	0	0	85	57.73	0	0	0.19	64.89	0	0	1093	55.44	0	0	2.47	67.91
Plesionika martia	0	0	0	100	0	0	0	100	0	0	3	103.93	0	0	0.01	103.93
Sergia robusta	0	0	13	57.51	0	0	0.03	62.31	0	0	226	50.46	0	0	0.52	54.56
Sergestes sp.	0	0	21	79.09	0	0	0.01	74.94	0	0	300	73.78	0	0	0.08	69.03
Macrura Reptantia																
Nephrops norvegicus	0	0	24	42.52	0	0	0.87	42.62	0	0	306	45.09	0	0	11.23	44.60
Anomura																
Munida intermedia	0	0	1	100	0	0	0	100	0	0	10	103.93	0	0	0.03	103.93
Munida iris rutllanti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura																
Macropodia longipes	6	77.87	0	0	0.01	75.15	0	0	51	82.78	0	0	0.13	79.34	0	0
Liocarcinus depurator	11	67.23	0	0	0.16	60.83	0	0	98	69.64	0	0	1.48	62.54	0	0

CV = coefficient of variation.

Table 4 - CPUE and density indices of the most important decapods caught in Argosaronikos during MEDITS-GR 97.

Species	Argosaronikos 1997															
	CPUE (Nb/h)				CPUE (kg/h)				Abundance (Nb/km^2)				Biomass (kg/km^2)			
	10-200 m		200-800 m		10-200 m		200-800 m		10-200 m		200-800 m		10-200 m		200-800 m	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Natantia																
Aristaeomorpha foliacea	0	0	1	73.29	0	0	0.02	84.39	0	0	14	74.78	0	0	0.23	87.74
Parapenaeus longirostris	360	71.06	101	60.21	2.32	74.11	0.87	65.17	4368	104.05	1293	61.24	28.17	110.41	11.08	66.82
Pasiphaea sivado	0	0	199	99.85	0	0	0.33	100.34	0	0	2513	104.53	0	0	4.15	105.06
Plesionika heterocarpus	22	101.18	28	76.91	0.04	101.18	0.04	77.12	268	152.89	359	93.39	0.47	152.89	0.57	93.62
Plesionika martia	0	0	50	76.97	0	0	0.29	77.86	0	0	636	74.95	0	0	3.69	75.93
Sergia robusta	0	0	24	66.70	0	0	0.03	80.54	0	0	313	69.25	0	0	0.38	83.98
Sergestes sp.	0	0	21	58.13	0	0	0.01	49.50	0	0	265	60.18	0	0	0.08	51.30
Macrura Reptantia																
Nephrops norvegicus	1	72.60	5	57.58	0.03	56.79	0.17	53.61	12	108.71	61	50.82	0.31	76.88	2.18	47.70
Anomura																
Munida intermedia	0	0	18	103.07	0	0	0.27	103.07	0	0	226	107.98	0	0	0.03	103.93
Munida iris rutllanti	50	66.33	5	70.67	0.07	59.32	0.01	77.51	609	74.67	67	67.33	0.90	73.33	0.13	80.95
Brachyura																
Macropodia longipes	1	48.37	0	0	0	51.25	0	0	15	46.74	0	0	0.02	49.67	0	0
Liocarcinus depurator	10	54.60	0	0	0.08	64.37	0	0	123	50.93	0	0	1.07	57.94	0	0

CV = coefficient of variation.

The catch was high in the 100-200 m zone (1,230 ind./h in 1996 and 657 ind./h in 1997). *Parapenaeus longirostris* was dominant (95% in 1996 and 78% in 1997), followed by *Munida iris rutllanti* (3% in 1996 and 11% in 1997).

The catch was also high in the 200-500 m zone (1,192 ind./h in 1996 and 870 ind./h in 1997). The most abundant species were *Munida intermedia* (34%), *Parapenaeus longirostris* (28%), *Pasiphaea sivado* (15%), *Plesionika heterocarpus* (9%) and *Sergia robusta* (6%) in 1996, and *Pasiphaea sivado* (54%), *Parapenaeus longirostris* (17%), *Plesionika heterocarpus* (8%) and *Munida intermedia* (5%) in 1997.

In the deepest zone (500-800 m), the catch ranged between 165 ind./h in 1996 and 189 ind./h in 1997. The most abundant species were *Munida intermedia* (57%), *Sergia robusta* (17%), *Polycheles typhlops* (10%) and *Plesionika martia* (9%) in 1996, and *Parapenaeus longirostris* (37%), *Plesionika martia* (34%), Sergestids (17%) and *Pasiphaea sivado* (6%) in 1997.

An analysis by categories showed that all shrimps were found on the slope, as in the Ionian Sea. However, in Argosaronikos, the highest abundance of *Parapenaeus longirostris* was obtained on the shelf, whereas *Plesionika heterocarpus* was also fished on the shelf in significant quantities in 1997 (tables 1, 2 and 4). *Nephrops norvegicus* was found mainly on the slope, *Munida intermedia* exclusively on the slope, and *Munida iris rutllanti* in higher quantities on the shelf. Most species of crabs were found on the shelf, but only negligible quantities on the slope.

Carapace length analysis

Carapace length distributions per area and depth zone were analyzed for the most commercially important species.

• *Aristaeomorpha foliacea*

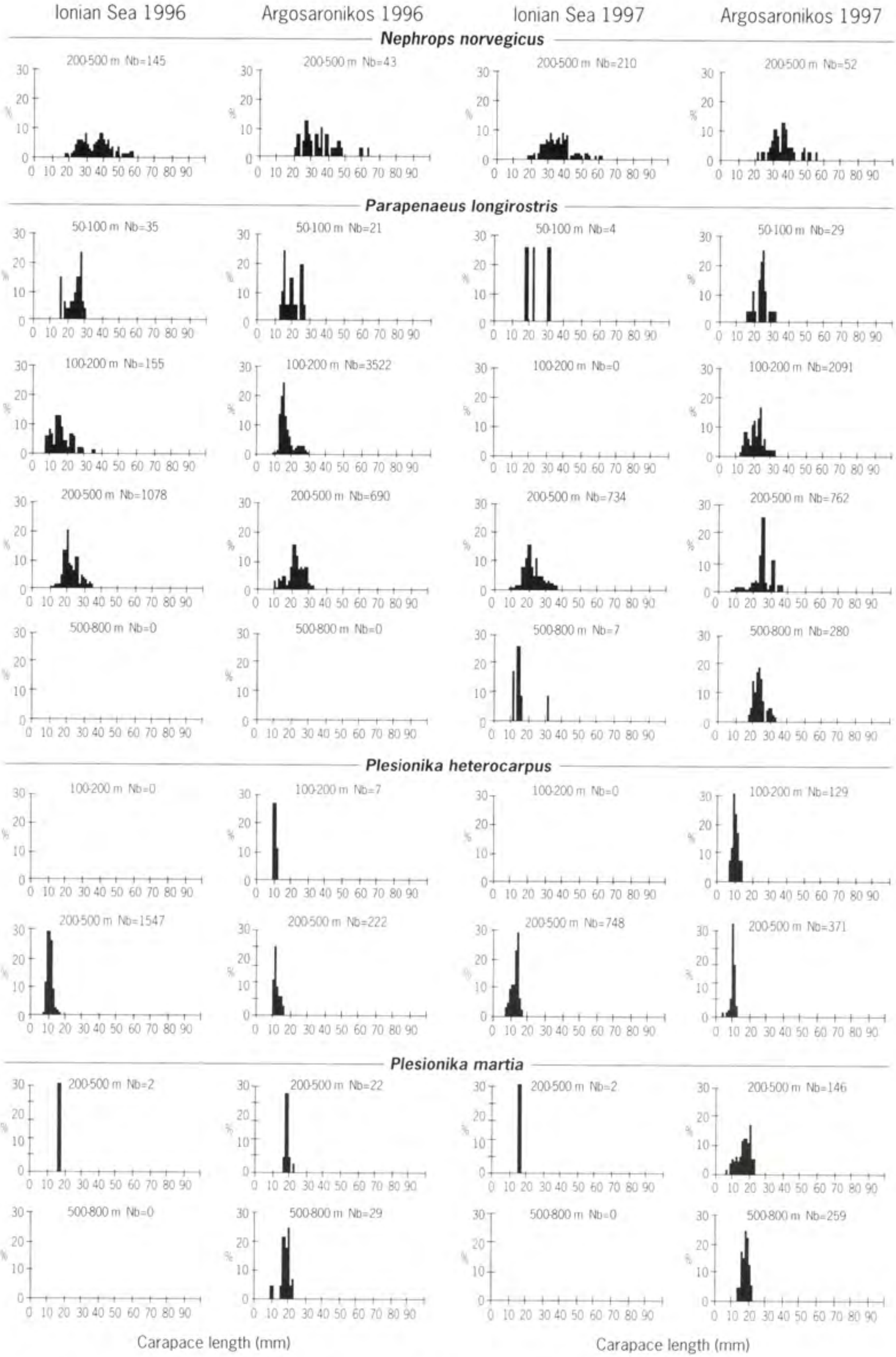
Very few specimens were found at depths of 200 m to 800 m in Argosaronikos (tables 2 and 4). Their CLs ranged between 32 mm and 51 mm in 1996 and 22 mm and 47 mm in 1997. This species was not caught in the Ionian Sea during the MEDITS surveys.

• *Nephrops norvegicus*

In the Ionian Sea, specimens were found almost exclusively in the 200-500 m zone where CL ranged from 18 mm to 61 mm. Most specimens had a CL of between 22 mm and 49 mm in 1996 and 25 and 42 mm in 1997. This species was also found in the region of Argosaronikos, mainly in the 200-500 m zone where the highest size range was observed, with CLs ranging from 22 to 63 mm in 1996 and 22 mm to 56 mm in 1997 (voir figure).

• *Parapenaeus longirostris*

In the Ionian Sea, this species was caught at depths of 50 m to 500 m in 1996, with CLs ranging from 8 mm to 35 mm. The smaller specimens were fished in the 100-200 m zone and the largest specimens (CL generally greater than 17 mm) in the 200-500 m zone where abundance was maximal. In 1997, this species was found almost exclusively in the 200-500 m zone, with CLs ranging from 9 mm to 37 mm (most specimens larger than 17 mm) (voir figure).



Carapace length distribution per depth zone of commercial shrimp species caught in the Ionian Sea and Argosaronikos during MEDITS-GR 96 and 97.

In Argosaronikos, the species was caught at depths of 50 m to 500 m in 1996, with minimum abundance in the 50-100 m zone. Abundance was maximal in the 100-200 m zone, where CLs ranged from 9 mm to 30 mm (specimens between 13 mm and 19 mm were dominant). In the 200-500 m zone, specimens had a CL between 10 mm and 32 mm (most larger than 20 mm). In 1997, the species was caught at depths of 50 m to 800 m, with minimum abundance in the 50-100 m zone and a maximum in the 100-200 m zone, as in 1996. Carapace length distribution showed a trend similar to that of 1996, with larger specimens (>20 mm) dominant in the deeper zones.

• *Plesionika heterocarpus*

In the Ionian Sea, this species was caught exclusively in the 200-500 m zone, with CLs ranging from 8 mm to 18 mm in both years (voir figure). In Argosaronikos, specimens were found at depths of 100 m to 500 m, with the greatest abundance in the 200-500 m zone. Carapace lengths ranged from 10 mm to 16 mm in 1996 and 6 mm to 13 mm in 1997, with a peak of 10 mm for the 100-200 m zone and 11 mm for the 200-500 m zone.

• *Plesionika martia*

In the Ionian Sea, this species was occasionally found in the 200-500 m zone (voir figure). In Argosaronikos, it was caught at depths of 200 m to 800 metres. Carapace lengths ranged from 18 to 22 mm in the 200-500 m zone and 11 mm to 22 mm in the 500-800 m zone in 1996, and from 7 mm to 24 mm in the 200-500 m zone and 14 mm to 22 mm in the 500-800 m zone in 1997.

Discussion

Among the species found in Argosaronikos in the present study, the following are not reported in the list of Aegean Sea decapods of Koukouras *et al.* (1992): *Pandalina profunda. Plesionika gigliolii and Munida intermedia.* Five specimens of *Pandalina profunda*, a rare deep-water species (Zariquiey Alvarez, 1968), were found in Argosaronikos in the 200-500 m zone during both years, and another was fished in the same depth range of the Ionian Sea in 1997. *Plesionika gigliolii* was found in the 200-500 m zone of both regions (10 specimens in Argosaronikos in 1997 and 4 in the Ionian Sea during both years of the survey). This depth range is in agreement with that indicated for the species by Zariquiey Alvarez (1968) and Fischer *et al.* (1987). Finally, *Munida intermedia* was fished in higher quantities than the previous species, mainly in the 200-500 m zone of both study regions, but also in the 500-800 m zone of Argosaronikos in 1996. A depth distribution for this species of 300 to 400 m was reported by Zariquiey Alvarez (1968). This species and *Munida rugosa* were also abundant in the Evoikos Gulf (Politou *et al.*, 1996).

A remarkable observation in this study was the absence or scarcity of some commercial species, such as *Aristeus antennatus*, which was not fished in either region, and *Aristaeomorpha foliacea*, which was fished in low numbers only in Argosaronikos (200-800 m). Both species have been reported in the Aegean Sea (Koukouras *et al.*, 1992; Mytilineou & Politou, 1997; Koukouras *et al.*, 1997b). For the Ionian Sea, the results of the Deep Water Fisheries project showed an important catch for both species. The surveys of this project were carried out in depths of 300 m to 800 m. At some stations during the summer of 1997, *Aristeus antennatus* exceeded 5 kg/h and *Aristaeomorpha foliacea* 15 kg/h (unpublished data). Another deep-water shrimp caught in large quantities (up to 6 kg/h) in the Ionian Sea during the surveys of the Deep Water Fisheries project was *Plesionika martia*. During the MEDITS surveys, this species was rarely caught in that region, but was more abundant in Argosaronikos (0.29 kg/h on the slope). This difference in the results of the two projects may be attributed to the different gear used. It has already been mentioned in reports of the MEDITS project that the gear used in the surveys is less efficient at great depths, mainly for demersal species. Another factor which may have affected the results for the two projects is the difference in haul points.

Despite a tendency to underestimate the abundance of decapods in deep waters, the above results indicate a greater number of commercial species on the slope and a very low number on the shelf (mainly at depths of less than 100 m). Moreover, larger individuals showed a tendency to inhabit deeper waters. The peak catch of *Parapenaeus longirostris* in the 100-200 m zone of Argosaronikos is not completely in agreement with this tendency. However, it is noteworthy that a high proportion of small specimens not observed in deeper waters was found in that zone.

These observations appear to be of interest for Greek fisheries. Bottom-trawling in Greece is presently performed mainly on the shelf, and in any event at depths of less than 400 metres. As a result, some deep-water shrimps, which are of high commercial value in other countries, are not found on the Greek market. An expansion of trawling to deeper waters might increase the catches of commercial species and at the same time reduce overfishing of the shallows. However, further research, using more efficient gear, needs to be carried out in the poorly explored deeper Greek waters.

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Preliminary investigation of factors affecting the spatial distribution and abundance of *Eledone cirrhosa* (Cephalopoda: Octopoda) in the Mediterranean Sea

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Abstract

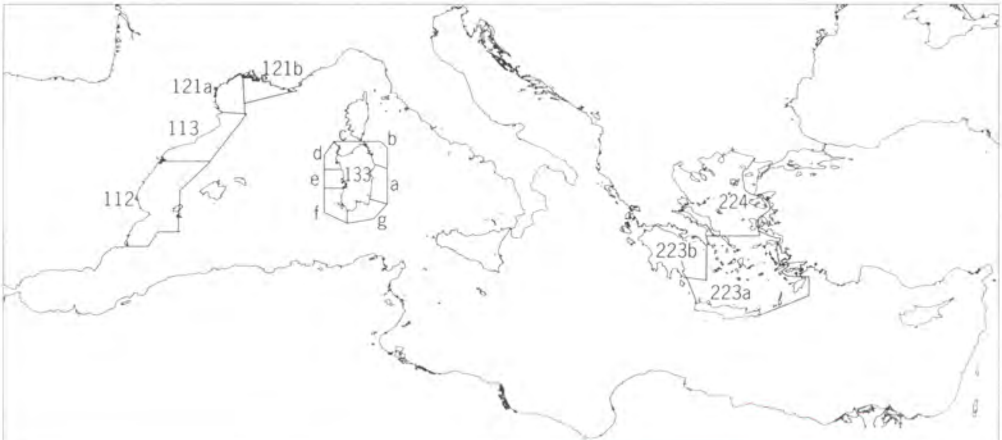
The present study concerns the distribution and abundance of *Eledone cirrhosa* (Lamarck, 1798) fished during two trawl surveys carried out in the summer of 1996 and 1997 within the framework of the MEDITS programme, an international bottom trawl survey designed to provide biological data on demersal resources along the coasts of the four Mediterranean countries of the European Union (Spain, France, Italy and Greece). *E. cirrhosa* was among the ten most abundant species in almost all MEDITS geographic areas and well-represented from 50 m to 500 m depths. General analysis of the data for the two years showed a great variability in species abundance and distribution among the various fishing areas of the Mediterranean, as well as interannual differences. Further analysis of catch per unit effort data on a station level within selected fishing areas, on the basis of multiple regression linear models, showed that the main factors affecting spatial variation of species abundance were depth and the shape of the continental shelf.

Introduction

Eledone cirrhosa is a medium-sized octopod, quite common in the Mediterranean and the northeastern Atlantic up to 67° N (Roper *et al.*, 1984). Despite the importance of this species for trawl fishing, it is generally pooled with *Eledone moschata* in Mediterranean fishery statistics, which makes it impossible to assess individual catch levels as an index of stock biomass. Results of previous studies indicate that *E. cirrhosa* is probably the most abundant benthic cephalopod species on the lower continental shelf and upper slope of the northwestern Mediterranean (Mangold *et al.*, 1971; Relini & Orsi Relini, 1984; Sanchez *et al.*, 1997), and the northern Aegean Sea (Papaconstantinou *et al.*, 1993, 1994), whereas it is outnumbered by *Eledone moschata* in the northern and middle Adriatic (Giovanardi, 1986). Although several authors have investigated various aspects of its biology, its role in the ecosystem is still poorly understood. It would seem of particular interest to study stock dynamics, as it has been suggested that shorter-living cephalopods could be subdominant predators which tend to increase their biomass when other species become depleted due to heavy fishing (Caddy, 1983).

Eledone cirrhosa is among the ten most abundant species in almost all MEDITS geographic areas (Bertrand *et al.*, 1996, 1998). The annual repetitive trawl surveys carried out along the coasts of European Mediterranean countries since 1994 within the framework of the MEDITS programme have provided useful data sets for analysis of species distribution patterns and response to environmental diversity on a Mediterranean scale. In this preliminary study, the effects of the continental shelf on the spatial abundance of *E. cirrhosa* were examined in four areas: the Aegean Sea, the eastern Mediterranean coasts of Spain, the Gulf of Lions and the Sardinian coasts (fig. 1, table 1).

Figure 1
Map of the Mediterranean Sea showing the study areas.



Materials and methods

The MEDITS study area during the 1996 and 1997 surveys included all trawlable areas off the Mediterranean coasts of European countries from 10 m to 800 m depths. Small sub-areas were defined within the waters of each country (Bertrand *et al.*, 2000). In addition, depth stratification was applied by subdividing the study area into five strata with the following bathymetric limits: 10, 50, 100, 200, 500 and 800 metres. The stations were distributed randomly inside each stratum to obtain a compromise between the constraints of statistics based on random sampling and those of geostatistics. Sampling was performed during late spring and summer, using an experimental trawl net (20 mm stretched mesh size in the codend) according to MEDITS protocols. The number of stations per stratum and sub-area in the four selected areas is indicated in table 1.

Table 1 - Number of stations and the frequency of *Eledone cirrhosa* in surveyed areas per bathymetric stratum.

Area	Sub-area	Stratum	Number of stations		*Eledone cirrhosa* presence %	
			1996	1997	1996	1997
Aegean Sea	Northern Aegean (224)	S1	7	6	14.3	33.3
		S2	13	13	53.8	84.6
		S3	14	15	71.4	93.3
		S4	21	21	52.4	90.5
		S5	9	8	0.0	0.0
	Southern Aegean (223a)	S1	2	2	0.0	0.0
		S2	8	12	0.0	16.7
		S3	14	13	0.0	23.1
		S4	20	25	40.0	36.0
		S5	8	8	0.0	12.5
	Argosaronikos Region (223b)	S1	2	2	0.0	0.0
		S2	4	3	25.0	66.7
		S3	7	8	71.4	75.0
		S4	4	5	25.0	60.0
		S5	2	4	0.0	25.0
Spanish Coasts	Alicante Area (112)	S1	6	4	0.0	25.0
		S2	21	20	42.9	65.0
		S3	8	7	75.0	100.0
		S4	7	8	71.4	62.5
		S5	7	6	0.0	0.0
	Catalan Sea (113)	S1	2	1	0.0	0.0
		S2	5	6	100.0	83.3
		S3	8	7	87.5	100.0
		S4	5	4	100.0	75.0
		S5	4	3	0.0	0.0
Gulf of Lions	Western part (121a)	S1	8	7	50.0	42.9
		S2	22	23	95.5	95.7
		S3	2	2	50.0	100.0
		S4	4	5	100.0	80.0
		S5	4	4	25.0	25.0
	Eastern part (121b)	S1	4	4	25.0	0.0
		S2	10	10	100.0	80.0
		S3	8	8	100.0	62.5
		S4	2	2	100.0	100.0
		S5	1	1	0.0	0.0
Sardinian Coasts	East coast (133a)	S1	3	3	33.3	33.3
		S2	2	2	100.0	50.0
		S3	2	2	50.0	100.0
		S4	3	3	100.0	100.0
		S5	3	3	0.0	33.3

Area	Sub-area	Stratum	Number of stations		*Eledone cirrhosa* presence %	
			1996	1997	1996	1997
Sardinian Coasts	Northeast coast (133b)	S1	4	4	50.0	50.0
		S2	6	6	100.0	66.7
		S3	2	2	100.0	100.0
		S4	4	4	100.0	100.0
		S5	3	3	66.7	100.0
	North coast (133c)	S1	3	3	0.0	0.0
		S2	3	3	33.3	100.0
		S3	3	3	100.0	100.0
		S4	2	2	100.0	100.0
		S5	1	1	100.0	100.0
	Northwest coast (133d)	S1	2	2	50.0	0.0
		S2	3	3	66.7	100.0
		S3	4	4	100.0	100.0
		S4	2	2	100.0	100.0
		S5	3	3	33.3	0.0
	Mid-west coast (133e)	S1	4	4	0.0	25.0
		S2	2	2	50.0	0.0
		S3	5	5	100.0	100.0
		S4	1	3	100.0	100.0
		S5	3	3	0.0	0.0
	Southwest coast (133f)	S1	2	2	0.0	0.0
		S2	4	4	50.0	100.0
		S3	11	11	90.9	81.8
		S4	10	10	90.0	90.0
		S5	4	6	0.0	66.7
	Southeast coast (133g)	S1	3	3	0.0	0.0
		S2	2	2	100.0	100.0
		S3	4	4	100.0	100.0
		S4	4	4	100.0	100.0
		S5	6	6	16.7	50.0

S1 = 10-50 m, S2 = 50-100 m, S3 = 100-200 m, S4 = 200-500 m, S5 = 500-800 m.

In every station, the catch per unit effort (CPUE) of *E. cirrhosa* was estimated by weight (g) and the number of individuals per fishing hour. The General Linear Model (GLM) method (McCullagh & Nedler, 1989), using the Statgraphics Plus 2.0 software program, was applied for standardization of catch per unit effort data (g/h, ind./h). The main factors used in the present model were area, year, depth or stratum, width of a 0-50 m depth zone, and distance from the coast. Two-way interactions were included in the model when estimable, as well as zero catch records. The model used in the analysis was as follows:

$\mathrm{Log}(\mathrm{CPUE}_{ijklm}+1) = c+Y_i+A_j+D_k+Z50_l/I50_l+S_m/P_m+\mathrm{interaction}$

where Log = the natural logarithm

c = the constant

Y_i = the effect of year i

A_j = the effect of sub-area j

D_k = the effect of the distance from the coast k

$Z50_l$ / $I50_l$ = the effect of the width of the 0-50 m bathymetric zone l or the distance from the 50 m isobath
S_m / P_m = the effect of the bathymetric stratum m or the depth in metres.

Each of these parameters was included in the model, provided that it accounted for at least 5% of the total variation. The coefficient of determination r^2 was considered to express the goodness-of-fit of the model with the data. All statistical inferences were based on a 0.05 significance level.

Results

Eledone cirrhosa was caught between 13 and 750 m of depth, but more frequently at depths ranging from 50 to 500 m (table 1). The standardized CPUE (kg/h) values of *E. cirrhosa* for 1996 and 1997, as well as the surface area percentage of each bathymetric stratum per sub-area, are shown in figure 2.
The variables accounting for the variation in CPUE of *E. cirrhosa* differed considerably between areas (table 2), which is probably indicative of the great diversity in bathymetric and hydrological conditions within the Mediterranean. An analysis of GLM results in relation to population characteristics in each geographic area is eventually to be performed.

Aegean Sea

The GLM fitted for the total area of the Aegean Sea was quite complex, accounting for 52-54% of the total variation and showing highly significant differences in CPUE indices among sub-areas, years and bathymetric zones. These differences were also apparent from standardized CPUE values per stratum in the three sub-areas (fig. 2).
The width of the bathymetric zone (0-50 m), which is highly variable in the Aegean Sea, was also a significant factor in the total variation. This parameter was very important in the Argosaronikos region (223b, fig. 1), indicating that distribution in a relatively limited area supposedly inhabited by a single population is influenced by the distance of the main bathymetric niche (>50 m) from the eutrophic coastal area.
Great interannual variation was observed in the North Aegean sub-area (224, fig. 1). In 1996, species abundance was much lower (fig. 2), while catch was made by a higher percentage of recruits (Bertrand *et al.*, 1998).
The total variation of CPUE can be understood better once the model is fitted for 1997 data (r^2= 58-66%), in which case it seems to depend mainly on the interaction of the bathymetric zone and the distance of the station from the coast, reflecting the variability of the continental shelf within this sub-area. The fitting of the model was not satisfactory (r^2 < 50%) in cases of low abundance of the species (N. Aegean Sea-1996, S. Aegean Sea).

Table 2 - General Linear Model analysis performed on log-transformed CPUE of *Eledone cirrhosa*, from different sub-areas separately and combined, for the MEDITS surveys of 1996 and 1997.

			Significance level of the coefficients											
Area	Proposed GLM	r^2%	Y	A	S	D	Z_{50}	I_{50}	A*Y	S*A	D*A	S(D)	D(S)	S(A)
Aegean Sea	A :Log (CPUE+1)= c+Y+A+S+Z_{50}+A*Y+S*A	53.70	0.0001	0.0035	0.0051		0.0088		0.0116	0.0211				
(223 + 224)	B : >> >>	52.05	0.0008	0.0033	0.0419		0.0089		0.0022	0.0079				
Argosaronikos	A :Log (CPUE+1)= c+D+Z_{50}+P*Z_{50}	54.50				0.0012	0.0001							
(223b)	B : >> >>	53.55				0.0193	0.0001							
Northern Aegean	A :Log (CPUE+1)= c+Y+D+I_{50}+S(D)	53.33	0.0000			0.0556		0.0248				0.0000		
(224)	B : >> >>	50.45	0.0000			0.0203		0.0128				0.0000		
N Aegean (1997)	A :Log (CPUE+1)= c+D+I_{50}+S(D)	65.80				0.0177		0.0100				0.0000		
	B : >> >>	58.23				0.0149		0.0101				0.0001		
E Spanish coasts	A :Log (CPUE+1)= c+A+S+Z_{50}+D*A	55.55		0.0289	0.0000		0.0120				0.0499			
(112 + 113)	B : >> >>	56.65		0.0014	0.0000		0.1000				0.0110			
Alicante area	A :Log (CPUE+1)= c+Z_{50}+S(D)	56.42					0.0002					0.0000		
(112)	B :Log (CPUE+1)= c+Y+Z_{50}+S(D)	61.00	0.0176				0.0000					0.0000		
Catalán Sea	A :Log (CPUE+1)= c+Z_{50}+S(D)	72.14					0.0258					0.0000		
(113)	B : >> >>	69.60					0.0005					0.0000		
Gulf of Lions	A :Log (CPUE+1)= c+D(S)+S(A)	56.23											0.0006	0.0027
(121)	B : >> >>	56.55											0.0005	0.0510
W Gulf of Lions	A :Log (CPUE+1)= c+S+D(S)	55.39			0.0175								0.0104	
(121a)	B :Log (CPUE+1)= c+D(S)	57.92											0.0044	
E Gulf of Lions	A :Log (CPUE+1)= c+Y+D(S)	58.83	0.0491										0.0000	
(121b)	B : >> >>	51.7	0.0481										0.0000	
Sardinia	A :Log (CPUE+1)= c+A+S+D*A	51.81		0.0001	0.0000						0.0196			
(133)	B : >> >>	59.69		0.0022	0.0000						0.0002			

A: in g/h, B: in Nb/h.

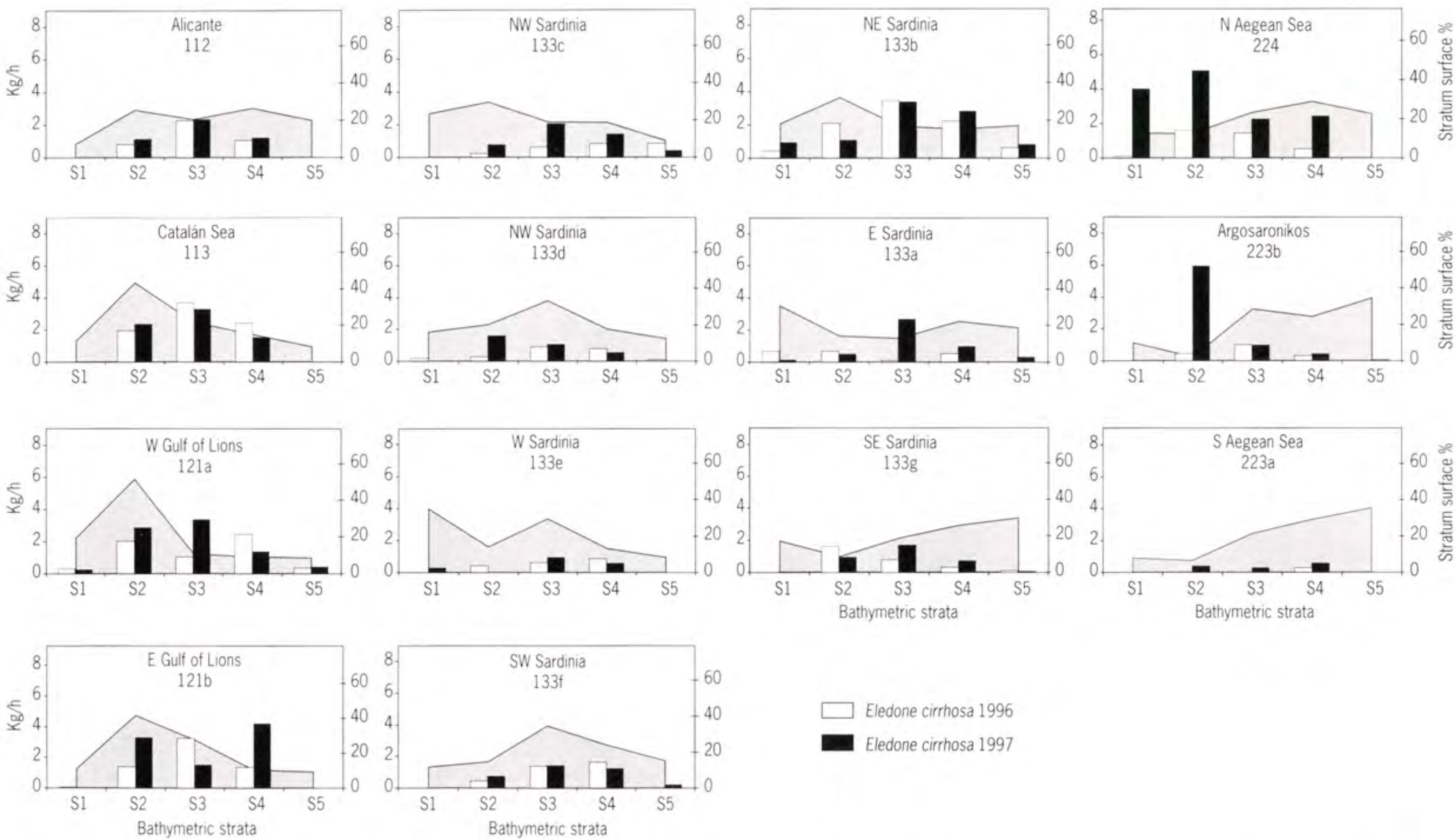


Figure 2 - Standardized CPUE (kg/h) values of *Eledone cirrhosa* for 1996 and 1997 per sub-area and stratum in selected areas: Aegean Sea, Gulf of Lions, East Spanish and Sardinian coasts.

Eastern Spanish coasts

Only the eastern part of the Spanish coast, where the species were more highly abundant, was considered in this study. The limit between the two sub-areas was situated at the delta of the Ebro River (37° 31' N). The sub-area of Alicante (112, fig. 1) included a more extended zone of continental shelf, while the Catalan Sea (113, fig. 1) was characterized by abruptly deeper waters. The fitting of the GLM showed a significant difference in CPUE indices among the sub-areas. When it was applied separately to each of the sub-areas, the interaction of the bathymetric zone and the distance from the coast, as well as the width of the first stratum, played a significant role in species distribution. Higher recruitment was observed in the Alicante sub-area in 1997 (Bertrand *et al.*, 1998), which explains the difference in the standardized number of individuals caught per hour (B, table 2) between the two years.

Gulf of Lions

The GLM accounted for 56% of total variation when applied to the whole area. There were marked differences in CPUE indices among the bathymetric zones of each area, as well as in the distances of the stations located in each stratum. GLM fitting in the western part of the Gulf of Lions (121a, fig. 1), where the 50-100 m bathymetric zone was dominant, showed that the stratum and the distance of the stations within a stratum played an important role in species distribution. Conversely, in the eastern part (121b, fig. 1), differences in CPUE indices were also significant between the two years, probably because of higher recruitment in this sub-area in 1997 (Bertrand *et al.*, 1998).

Sardinian coasts

The geographic positions of the sub-areas around Sardinia (133, fig. 1) could account for the highly significant differences in their CPUE indices (table 2), as shown by the application of the GLM. However, the distribution per bathymetric zone seems quite homogeneous, with higher CPUE values at depths of 100 to 200 m, which could explain the important role of the stratum parameter. The important effect of the interaction of distance with the sub-area is probably indicative of differences in the dimensions of the strata in the sub-areas. The distribution of the recruits (Bertrand *et al.*, 1998), which generally represent a high percentage of catches, differed between sub-areas, showing a wider bathymetric range in those with a narrower continental shelf.

General remarks

The GLM accounted for only 52-60% of total variation when applied to wider areas, but achieved higher levels in more homogeneous sub-areas (table 2). In all cases, differences in CPUE indices were highly significant ($p < 0.1$) between sub-areas and bathymetric zones, while the distance from the coast and the width of the bathymetric zone (0-50 m) played a greater role in areas where the width of the continental shelf was variable. In sub-areas in which population structure differed between the two years due to recruitment, considerable annual variation in CPUE indices was apparent.

Discussion

The life-span of *E. cirrhosa* does not exceed two years (Boyle, 1983; Tursi *et al.*, 1995; Lefkaditou & Papaconstantinou, 1995), and recruitment occurs at an age of 4-8 months (Boyle, 1983). Thus, one year class composes the main part of the stock biomass, which means that changes in annual fishing intensity or environmental conditions may markedly affect its numbers.

Moreover, the period of late spring and summer, when MEDITS sampling is carried out, is critical for this species, which is characterized by seasonal sexual maturity. A comparison of size frequency distributions between areas showed that the percentage of recruits (ML < 5 cm) was relatively higher in samples from Spanish sub-areas, the Gulf of Lions and the Sardinian coasts than in those from the Aegean Sea. This was probably due to temporal variations in reproductive maturity and recruitment between the western and eastern Mediterranean, for which previous evidence is available. The maximum incidence of full maturation of females occurs in late spring in the northwestern Mediterranean (Mangold-Wirtz, 1963; Moriyasu, 1988) and in late summer in the northeastern Mediterranean (Papaconstantinou *et al.*, 1994; Tursi *et al.*, 1995). Higher biomass was also observed during this period by Wurtz *et al.* (1992) and Papaconstantinou *et al.* (1994) respectively, whereas the high post-spawning mortality of the species was responsible for the very low numbers of adults after the breeding season (which usually coincides with maximum recruitment). These factors have a strong influence on seasonal species biomass and distribution. Consequently, the catches showed high variability in weight and number according to the demographic structure of the sampled population.

Obviously, additional factors related to hydrologic characteristics and the nature of bottom and epifauna composition may provide more likely explanations for the high variability observed, even for a given sub-area and sampling period.

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Chapter V

Species composition

Ichthyofauna caught during the MEDITS-ES cruises (1994 to 1997) in the Iberian western Mediterranean

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Abstract

This study provides the total inventory of fish species (192) caught during the research cruises of the MEDITS-ES project (1994 to 1997). Among the total number of species, 109 were captured during all four cruises, 21 in only three, 26 in two and 36 in one (this last group was thus considered as occasional). This project is important not only for updating of the ichthyofauna inhabiting specific regions (*e.g.* the Iberian western Mediterranean), but also because it was the first time that teams from different countries (Spain, France, Italy, and Greece) used a standardized approach (same bathymetric range, bottom trawl gear and season) to compare results in the respective localities (Iberian Mediterranean, Gulf of Lions, Ligurian, Adriatic, Ionian and Aegean Seas) where they operated.

Introduction

In this age of high technology, a faunistic inventory is often considered to consist solely of a list of names in which more or less complete sets of organisms are arranged, even though different forums have insisted on an understanding and preservation of aspects related to biodiversity. A faunistic inventory, when carried out in terms of scientific bases and criteria, not only provides proof of the occurrence of several organisms at a specific time and locality but is itself an indicator of the present state of the communities and an indicator of possible changes in their interrelations. This allows us, when necessary, to reorganize our knowledge of their intrinsic dynamics periodically. In effect, good naturalistic inventories are an updating of events that are not easily detectable.

For these reasons, every organism captured during the course of a large-scale trawl survey carried out from 1994 to 1997 along the Mediterranean Spanish coasts was patiently and minutely catalogued.

The collected material consisted of several zoological groups, and each specialist is to report the results for his subject, as appropriate. The present paper considers the most numerous group, *i.e.* the ichthyofauna, which supplied the largest part of the gathered biomass. The complete list of captured species is given as well as related information (unpublished in some cases).

Materials and methods

The data were collected during four surveys (one per year from 1994 to 1997) as part of the MEDITS-ES (International bottom trawl survey in the Mediterranean Sea) project financed by the European Union, DG XIV. During these surveys, a total of 400 hauls were carried out between the 25 and 800 m isobaths along the coast of the Iberian western Mediterranean (from the Strait of Gibraltar to Cape Creus), according to the complete criteria of the MEDITS sampling protocol. The sampling was stratified by depth: 25-50 m, 51-100 m, 101-200 m, 201-500 m and 501-800 m. All samples were collected with the same standardized MEDITS bottom trawl gear at approximately the same locations each year and during the same season (late spring, May).
The material and the information obtained were entered into an inventory including all the fish species caught during these surveys. The nomenclature and binomial authorship are in accordance with the basic criteria established by the FNAM (Whitehead *et al.*, 1984-1986) and supplemented with the most updated referenced literature.

Results

A total of 192 species were identified, including 109 found during all four cruises. These are among the commercial species accessible to trawl-fishing activity and caught at all times of the year. They are considered to live permanently at the depth intervals investigated. Twenty-one species were caught in only three cruises and 26 in two, which can be attributed to seasonality (end of spring/start of summer) and pelagic behaviour. Finally, 36 species were caught in only one cruise and can therefore be considered as occasional. All data are reported in the table.

Alphabetical taxonomic list of the ichthyofauna studied during the MEDITS cruises carried out in late spring during the years 1994 to 1997 from the Strait of Gibraltar to Cape Creus (Iberian western Mediterranean).

No.	Species	Family	a	b	c	d	rdm
1	*Alepocephalus rostratus* Risso, 1820	Alepocephalidae	1	1	1	1	545-798
2	*Anguilla anguilla* (Linnaeus, 1758)	Anguillidae	0	0	0	1	412-414
3	*Anthias anthias* (Linnaeus, 1758)	Serranidae	1	1	1	1	47-138
4	*Antonogadus megalokynodon* (Kolombatovic, 1894)	Gadidae	1	1	1	1	45-740
5	*Aphia minuta mediterranea* De Buen, 1931	Gobiidae	0	1	1	1	26-116
6	*Apterichthus caecus* (Linnaeus, 1758)	Ophichthidae	0	0	0	1	145-152
7	*Argentina sphyraena* (Linnaeus, 1758)	Argentinidae	1	1	1	1	88-360
8	*Argyropelecus hemigymnus* Cocco, 1829	Sternoptychidae	1	1	1	1	113-798
9	*Arnoglossus imperialis* (Rafinesque, 1810)	Bothidae	1	1	1	1	46-147
10	*Arnoglossus laterna* (Walbaum, 1792)	Bothidae	1	1	1	1	25-319
11	*Arnoglossus rueppelli* (Cocco, 1844)	Bothidae	1	1	1	1	88-620
12	*Arnoglossus thori* Kyle, 1913	Bothidae	1	1	1	1	25-267

No.	Species	Family	a	b	c	d	rdm
13	*Aspitrigla cuculus* (Linnaeus, 1758)	Triglidae	1	1	1	1	56-216
14	*Aspitrigla obscura* (Linnaeus, 1764)	Triglidae	1	1	1	1	25-142
15	*Aulopus filamentosus* (Bloch, 1792)	Aulopidae	0	0	1	1	106-427
16	*Bathypterois mediterraneus* Bauchot, 1962	Chlorophthalmidae	0	0	0	1	657-663
17	*Bathysolea profundicola* (Vaillant, 1888)	Soleidae	1	1	1	1	184-635
18	*Bellottia apoda* Giglioli, 1883	Bythitidae	1	0	0	0	338-341
19	*Benthosema glaciale* (Reinhardt, 1837)	Myctophidae	1	1	1	1	74-798
20	*Blennius ocellaris* Linnaeus, 1758	Blenniidae	1	1	1	1	25-253
21	*Boops boops* (Linnaeus, 1758)	Sparidae	1	1	1	1	26-293
22	*Borostomias antarcticus* (Lönnberg, 1905)	Astronesthidae	0	0	1	1	585-798
23	*Callionymus maculatus* Rafinesque-Schmaltz, 1810	Callionymidae	1	1	1	1	60-347
24	*Callionymus risso* Le Sueur, 1814	Callionymidae	0	1	0	1	33-81
25	*Capros aper* (Linnaeus, 1758)	Caproidae	1	1	1	1	40-600
26	*Caranx ronchus* E. Geoffroy Saint-Hilaire, 1817	Carangidae	0	0	1	1	26-126
27	*Carapus acus* (Brünnich, 1768)	Carapidae	1	1	1	1	45-490
28	*Cataetyx alleni* (Byrne, 1906)	Bythitidae	0	1	1	1	460-754
29	*Centracanthus cirrus* Rafinesque, 1810	Centracanthidae	1	1	0	0	95-124
30	*Centrolophus niger* (Gmelin, 1789)	Centrolophidae	0	1	1	1	345-798
31	*Centrophorus uyato* (Rafinesque, 1810)	Squalidae	1	0	1	1	375-679
32	*Cepola rubescens* Linnaeus, 1766	Cepolidae	1	1	1	1	26-179
33	*Ceratoscopelus maderensis* (Lowe, 1839)	Myctophidae	1	1	1	1	137-775
34	*Citharus linguatula* (Linnaeus, 1758)	Citharidae	1	1	1	1	26-293
35	*Coelorhynchus coelorhynchus* (Risso, 1820)	Macrouridae	1	1	1	1	216-643
36	*Coelorhynchus labiatus* Tortonese, 1970	Macrouridae	0	1	0	0	741-747
37	*Conger conger* Linnaeus, 1758	Congridae	1	1	1	1	26-790
38	*Crystallogobius linearis* (von Düben, 1845)	Gobiidae	1	0	0	1	58-87
39	*Cyclothone pygmaea* Jespersen & Taning, 1926	Gonostomatidae	1	1	1	0	339-661
40	*Chauliodus sloani* Schneider, 1801	Chaulidontidae	1	1	1	1	284-790
41	*Chimaera monstrosa* Linnaeus, 1758	Chimaeridae	1	1	1	1	324-790
42	*Chlopsis bicolor* Rafinesque, 1810	Xenocongridae	0	1	0	1	256-319
43	*Chlorophthalmus agassizi* Bonaparte, 1840	Chlorophthalmidae	1	1	1	1	172-582
44	*Dactylopterus volitans* (Linnaeus, 1758)	Dactylopteridae	0	0	0	1	35-39
45	*Dalatias licha* (Bonnaterre, 1788)	Squalidae	1	1	1	1	406-790
46	*Deltentosteus quadrimaculatus* (Valenciennes, 1837)	Gobiidae	1	1	1	1	25-282
47	*Dentex dentex* (Linnaeus, 1758)	Sparidae	1	0	0	0	42
48	*Dentex maroccanus* Valenciennes, 1830	Sparidae	0	0	0	1	73-162
49	*Diaphus holti* Taning, 1918	Myctophidae	0	1	0	1	412-612
50	*Dicentrarchus labrax* (Linnaeus, 1758)	Moronidae	0	1	0	1	26-49
51	*Diplecogaster bimaculata* (Bonnaterre, 1788)	Gobiesocidae	1	0	1	1	26-60
52	*Diplodus annularis* (Linnaeus, 1758)	Sparidae	1	1	1	1	26-88
53	*Diplodus cervinus* (Lowe, 1841)	Sparidae	0	1	0	0	26-88
54	*Diplodus puntazzo* (Cetti, 1777)	Sparidae	0	1	0	0	51-53
55	*Diplodus sargus* (Linnaeus, 1758)	Sparidae	0	1	1	1	47-53
56	*Diplodus vulgaris* (E. Geoffroy Saint-Hilaire, 1817)	Sparidae	1	1	1	1	26-101
57	*Dysomma brevirostre* (Facciolà, 1887)	Synaphobranchidae	0	0	0	1	518-528
58	*Echelus myrus* (Linnaeus, 1758)	Ophichthidae	1	1	1	1	45-342

No.	Species	Family	a	b	c	d	rdm
59	*Echiodon dentatus* (Cuvier, 1829)	Carapidae	1	0	1	0	301-480
60	*Electrona rissoi* (Cocco, 1829)	Myctophidae	1	1	1	1	398-690
61	*Engraulis encrasicolus* (Linnaeus, 1758)	Engraulidae	1	1	1	1	26-158
62	*Epigonus constanciae* (Giglioli, 1880)	Apogonidae	0	0	1	0	467-471
63	*Epigonus denticulatus* Dieuzeide, 1950	Apogonidae	1	1	1	1	230-723
64	*Epigonus telescopus* (Risso, 1810)	Apogonidae	1	1	1	1	216-790
65	*Eretmophorus kleinenbergi* Giglioli, 1889	Moridae	1	1	0	0	580-681
66	*Etmopterus spinax* (Linnaeus, 1758)	Squalidae	1	1	1	1	269-798
67	*Eutrigla gurnardus* (Linnaeus, 1758)	Triglidae	1	1	1	1	38-191
68	*Evermannella balbo* (Rissso, 1820)	Evermannellidae	1	0	1	0	506-661
69	*Gadella maraldi* (Risso, 1810)	Moridae	0	1	1	1	337-523
70	*Gadiculus argenteus* Guichenot, 1850	Gadidae	1	1	1	1	74-643
71	*Galeus melastomus* Rafinesque, 1810	Scyliorhinidae	1	1	1	1	255-798
72	*Glossanodon leioglossus* (Valenciennes, 1848)	Argentinidae	0	1	1	1	118-313
73	*Gnathophis mystax* (Delaroche, 1800)	Congridae	1	1	1	1	80-723
74	*Gobius geniporus* Valenciennes, 1837	Gobiidae	1	0	0	0	138-147
75	*Gobius niger* Linnaeus, 1758	Gobiidae	1	1	1	1	33-144
76	*Gonichthys coccoi* (Cocco, 1829)	Myctophidae	0	0	1	0	633-643
77	*Gonostoma denudatum* Rafinesque, 1810	Gonostomatidae	0	0	0	1	480-490
78	*Helicolenus dactylopterus* (Delaroche, 1809)	Scorpaenidae	1	1	1	1	63-790
79	*Heptranchias perlo* (Bonnaterre, 1788)	Hexanchidae	0	1	0	0	423-433
80	*Hoplostethus mediterraneus* Cuvier, 1829	Trachichthyidae	1	1	1	1	230-798
81	*Hygophum benoiti* (Cocco, 1838)	Myctophidae	1	1	0	0	267-754
82	*Hymenocephalus italicus* Giglioli, 1884	Macrouridae	1	1	1	1	315-798
83	*Lampanyctus crocodrilus* (Risso, 1810)	Myctophidae	1	1	1	1	74-798
84	*Lepidion lepidion* (Risso, 1810)	Moridae	1	1	1	1	580-798
85	*Lepidopus caudatus* (Euphrasen, 1788)	Trichiuridae	1	1	1	1	43-714
86	*Lepidorhombus boscii* (Risso, 1810)	Scophthalmidae	1	1	1	1	96-692
87	*Lepidorhombus whiffiagonis* (Walbaum, 1792)	Scophthalmidae	0	0	1	0	513
88	*Lepidotrigla cavillone* (Lacepède, 1801)	Triglidae	1	1	1	1	35-216
89	*Lepidotrigla dieuzeidei* Adouin *in* Blanc & Hureau, 1973	Triglidae	0	0	1	0	144-146
90	*Lesueurigobius friesii* (Malm, 1874)	Gobiidae	1	1	1	1	33-347
91	*Lesueurigobius sanzoi* (De Buen, 1918)	Gobiidae	1	1	1	1	43-342
92	*Lesueurigobius suerii* (Risso, 1810)	Gobiidae	0	1	0	1	115-347
93	*Liza aurata* (Risso, 1810)	Mugilidae	0	0	1	0	37-40
94	*Liza ramada* (Risso, 1826)	Mugilidae	0	0	0	1	36-39
95	*Lobianchia dofleini* (Zugmayer, 1911)	Myctophidae	1	1	1	1	286-780
96	*Lophius budegassa* Spinola, 1807	Lophiidae	1	1	1	1	33-760
97	*Lophius piscatorius* Linnaeus, 1758	Lophiidae	1	1	1	1	42-785
98	*Macroramphosus scolopax* (Linnaeus, 1758)	Macroramphosidae	1	1	1	1	40-332
99	*Maurolicus muelleri* (Gmelin, 1788)	Sternoptychidae	1	1	1	1	74-645
100	*Melanostigma atlanticum* Koefoed, 1952	Zoarcidae	1	1	1	1	398-690
101	*Merluccius merluccius* (Linnaeus, 1758)	Merlucciidae	1	1	1	1	26-723
102	*Microchirus acevia* (Capello, 1867)	Soleidae	1	0	1	0	56-60
103	*Microchirus boscanion* Chabanaud, 1926	Soleidae	0	0	1	1	43-126
104	*Microchirus ocellatus* (Linnaeus, 1758)	Soleidae	0	1	0	0	51-53

No.	Species	Family	a	b	c	d	rdm
105	*Microchirus variegatus* (Donovan, 1808)	Soleidae	1	1	1	0	40-124
106	*Micromesistius poutassou* (Risso, 1826)	Gadidae	1	1	1	1	64-798
107	*Mola mola* (Linnaeus, 1758)	Molidae	1	0	0	1	26-60
108	*Molva dipterygia macrophthalma* (Rafinesque, 1810)	Gadidae	1	1	1	1	95-612
109	*Molva molva* (Linnaeus, 1758)	Gadidae	0	0	1	0	159-433
110	*Monochirus hispidus* Rafinesque, 1814	Soleidae	0	1	0	0	42-43
111	*Mora moro* (Risso, 1810)	Moridae	1	1	1	1	455-747
112	*Mullus barbatus* Linnaeus, 1758	Mullidae	1	1	1	1	26-188
113	*Mullus surmuletus* Linnaeus, 1758	Mullidae	1	1	1	1	26-460
114	*Mustelus mustelus* (Linnaeus, 1758)	Triakidae	1	0	0	0	56-60
115	*Myctophum punctatum* Rafinesque, 1810	Myctophidae	1	1	1	1	216-780
116	*Nemichthys scolopaceus* Richardson, 1848	Nemichthyidae	1	1	1	1	124-798
117	*Nettastoma melanurum* Rafinesque, 1810	Nettastomatidae	0	1	1	1	418-798
118	*Nezumia aequalis* (Günther, 1878)	Macrouridae	1	1	1	1	230-798
119	*Notacanthus bonapartei* Risso, 1840	Notacanthidae	1	1	1	1	398-798
120	*Notolepis rissoi* (Bonaparte, 1840)	Paralepididae	1	1	1	1	286-785
121	*Notoscopelus elongatus* (Costa, 1844)	Myctophidae	0	1	1	1	216-704
122	*Ophichthus rufus* (Rafinesque, 1810)	Ophichthidae	1	1	1	1	41-663
123	*Ophidion barbatum* Linnaeus, 1758	Ophidiidae	1	1	1	1	36-338
124	*Ophidion rochei* Müller, 1845	Ophidiidae	1	1	1	0	40-236
125	*Ophisurus serpens* (Linnaeus, 1758)	Ophichthidae	1	0	1	1	64-338
126	*Oxynotus centrina* (Linnaeus, 1758)	Oxynotidae	1	0	0	1	184-414
127	*Pagellus acarne* (Risso, 1826)	Sparidae	1	1	1	1	26-714
128	*Pagellus bogaraveo* (Brünnich, 1768)	Sparidae	1	1	1	1	42-785
129	*Pagellus erythrinus* (Linnaeus, 1758)	Sparidae	1	1	1	1	25-141
130	*Pagrus pagrus* (Linnaeus, 1758)	Sparidae	1	1	1	1	40-139
131	*Paralepis speciosa* Belloti, 1878	Paralepididae	0	1	1	0	453-798
132	*Paraliparis leptochirus* (Tortonese, 1960)	Liparididae	1	1	1	1	398-754
133	*Peristedion cataphractum* (Linnaeus, 1758)	Peristediidae	1	1	1	1	46-319
134	*Phycis blennoides* (Brünnich, 1768)	Gadidae	1	1	1	1	88-798
135	*Phycis phycis* (Linnaeus, 1766)	Gadidae	0	0	1	0	47-88
136	*Polyacanthonotus rissoanus* (Filippi & Vérany, 1859)	Notacanthidae	0	1	1	0	653-798
137	*Polyprion americanus* (Schneider, 1801)	Serranidae	0	0	0	1	235-295
138	*Pomatomus saltator* (Linnaeus, 1766)	Pomatomidae	1	0	0	0	38-40
139	*Pomatoschistus marmoratus* (Risso, 1810)	Gobiidae	1	1	1	1	40-270
140	*Psetta maxima maxima* (Linnaeus, 1758)	Scophthalmidae	1	0	0	0	112-114
141	*Raja asterias* Delaroche, 1809	Rajidae	1	1	1	1	26-96
142	*Raja circularis* Couch, 1838	Rajidae	0	0	0	1	629-642
143	*Raja clavata* Linnaeus, 1758	Rajidae	1	1	1	1	26-281
144	*Raja miraletus* Linnaeus, 1758	Rajidae	0	1	0	1	80-216
145	*Raja montagui* Fowler, 1910	Rajidae	1	1	0	0	117-270
146	*Raja naevus* Müller & Henle, 1841	Rajidae	1	1	0	1	124-147
147	*Raja oxyrhinchus* Linnaeus, 1758	Rajidae	0	1	0	0	520-523
148	*Raja polystigma* Regan, 1913	Rajidae	1	1	1	1	40-318
149	*Rhynchogadus hepaticus* (Facciolà, 1884)	Moridae	0	0	1	0	513-533
150	*Sardina pilchardus* (Walbaum, 1792)	Clupeidae	1	1	1	1	26-143

No.	Species	Family	a	b	c	d	rdm
151	*Sardinella aurita* Valenciennes, 1847	Clupeidae	1	1	1	1	26-91
152	*Scomber japonicus* Houttuyn, 1782	Scombridae	1	1	1	1	42-77
153	*Scomber scombrus* Linnaeus, 1758	Scombridae	1	0	1	1	29-158
154	*Scophthalmus rhombus* (Linnaeus, 1758)	Scophthalmidae	1	1	0	0	43-76
155	*Scorpaena elongata* Cadenat, 1943	Scorpaenidae	1	0	1	1	92-293
156	*Scorpaena loppei* Cadenat, 1943	Scorpaenidae	0	0	1	1	105-138
157	*Scorpaena notata* Rafinesque, 1810	Scorpaenidae	1	1	1	1	26-147
158	*Scorpaena porcus* Linnaeus, 1758	Scorpaenidae	1	1	1	1	26-91
159	*Scorpaena scrofa* Linnaeus, 1758	Scorpaenidae	1	1	1	1	51-97
160	*Scyliorhinus canicula* (Linnaeus, 1758)	Scyliorhinidae	1	1	1	1	42-612
161	*Serranus cabrilla* (Linnaeus, 1758)	Serranidae	1	1	1	1	26-170
162	*Serranus hepatus* (Linnaeus, 1758)	Serranidae	1	1	1	1	25-370
163	*Solea vulgaris* Quensel, 1806	Soleidae	1	1	1	1	42-200
164	*Sphyraena sphyraena* (Linnaeus, 1758)	Sphyraenidae	0	0	0	1	36-39
165	*Spicara flexuosa* Rafinesque, 1810	Centracanthidae	1	1	1	1	26-128
166	*Spicara smaris* (Linnaeus, 1758)	Centracanthidae	1	1	1	1	40-158
167	*Spondyliosoma cantharus* (Linnaeus, 1758)	Sparidae	0	1	0	1	43-91
168	*Sprattus sprattus* (Linnaeus, 1758)	Clupeidae	0	0	0	1	88-91
169	*Stomias boa boa* (Risso, 1810)	Stomiidae	1	1	1	1	147-785
170	*Stromateus fiatola* Linnaeus, 1758	Stromateidae	0	0	0	1	36-39
171	*Symbolophorus veranyi* (Moreau, 1888)	Myctophidae	1	1	0	1	267-775
172	*Symphurus ligulatus* (Cocco, 1844)	Cynoglossidae	1	1	1	1	277-785
173	*Symphurus nigrescens* Rafinesque, 1810	Cynoglossidae	1	1	1	1	40-760
174	*Synchiropus phaeton* (Günther, 1861)	Callionymidae	1	1	1	1	115-580
175	*Syngnathus acus* Linnaeus, 1758	Syngnathidae	0	0	1	0	26-28
176	*Syngnathus phlegon* Risso, 1826	Syngnathidae	0	1	0	1	80-91
177	*Torpedo marmorata* Risso, 1810	Torpedinidae	1	1	1	1	26-292
178	*Torpedo nobiliana* Bonaparte, 1835	Torpedinidae	1	1	1	0	165-655
179	*Trachinus draco* Linnaeus, 1758	Trachinidae	1	1	1	1	26-216
180	*Trachurus mediterraneus* (Steindachner, 1868)	Carangidae	1	1	1	1	25-158
181	*Trachurus picturatus* (T.E. Bowdich, 1825)	Carangidae	1	1	1	1	40-690
182	*Trachurus trachurus* (Linnaeus, 1758)	Carangidae	1	1	1	1	25-690
183	*Trachyrhynchus trachyrhynchus* (Risso, 1810)	Macrouridae	1	1	1	1	400-798
184	*Trachyscorpia cristulata echinata* (Koelhler, 1896)	Scorpaenidae	1	1	1	1	688-790
185	*Trigla lucerna* Linnaeus, 1758	Triglidae	1	0	1	1	26-88
186	*Trigla lyra* Linnaeus, 1758	Triglidae	1	1	1	1	90-420
187	*Trigloporus lastoviza* (Brünnich, 1768)	Triglidae	1	1	1	1	26-124
188	*Trisopterus minutus capelanus* (Lacepède, 1800)	Gadidae	1	1	1	1	36-216
189	*Umbrina ronchus* Valenciennes, 1843	Sciaenidae	0	1	1	1	33-83
190	*Uranoscopus scaber* Linnaeus, 1758	Uranoscopidae	1	1	1	1	42-150
191	*Vinciguerria poweriae* (Cocco, 1838)	Photichthyidae	0	1	0	0	387-612
192	*Zeus faber* Linnaeus, 1758	Zeidae	1	1	1	1	42-293

Explanation of the table headings: No.: numeration code; Species: full taxonomic name; Family: family to which the binomial belongs; a: presence (1) or absence (0) in the 1994 cruise; b: same for the 1995 cruise; c: same for the 1996 cruise; d: same for the 1997 cruise; rdm: minimum and maximum depth range (in metres) at which species were found for the whole set of cruises.

Discussion

Frequent species will not be considered here, but rather those with particular features or belonging to the occasional group. For instance, the catch of a pregnant female *Conger conger*, whose gonads weighed 8 kg and the specimen 40 kg in total, was quite unusual. Moreover, the presence of *Microchirus boscanion* Chabanaud, 1926, is possibly the first recording for the whole Mediterranean.

The current controversy about the validity of the binomial *Centrophorus uyato* (Rafinesque, 1810) is still ongoing. The existing identification keys separating it from *C. granulosus* (Schneider, 1801) are not completely satisfactory for scientists since, for example, captured specimens (mature males and females of the same size as well as young specimens) have shown contradictory features not properly reflected in the literature (Krefft & Tortonese, 1973; Compagno, 1984; Capapé, 1985; Fredj & Maurin, 1987; Muñoz-Chapuli & Ramos, 1989).

The capture of one of the 36 species considered as occasional was due to different causes: (i) the type of sampling carried out (depth intervals and type of ground sampled), (ii) the characteristics and geometry of the fishing gear, and (iii) the particular behaviour and life cycle of these species.

In terms of each of these three aspects and leaving aside their abundance and ways of association, it may be inferred that the species *Gonichthys coccoi*, *Gonostoma denudatum*, *Liza aurata*, *Liza ramada*, *Polyprion americanus*, *Pomatomus saltator*, *Sphyraena sphyraena*, *Sprattus sprattus*, *Stromateus fiatola*, and *Vinciguerria poweriae* present a pelagic, pelagic-neritic or mesopelagic behaviour. Consequently, they are rarely captured using a bottom trawl with a relatively small vertical opening, such as the one used in this study.

The capture of *Eretmophorus kleinenbergi* and *Rhynchogadus hepaticus* is of very special interest, though related (but scarce) information exists. These two exceptional species are catalogued in the literature as having pelagic behaviour. Their catches during these or other cruises (Lloris *et al.*, 1994) were always at the same season of the year (end of spring), and their guts contained the same type of copepod (Calanoidea) which inhabits the deep substratum where sampling was carried out.

The presence of species with demersal or benthic habits, whether caught in shallower waters or at great depths, may have been due to the following factors: (i) they were caught at the extreme limits of their usual bathymetric distribution, (ii) their life above rocky grounds does not make them suitable for benthic trawling and/or (iii) they live in estuarine habitats or have a catadromous behaviour. Such is the case for *Anguilla anguilla*, *Apterichthus caecus*, *Syngnathus acus*, *Diplodus cervinus*, *Diplodus puntazzo*, *Dentex dentex*, *Dactylopterus volitans*, *Gobius geniporus*, *Microchirus ocellatus*, *Monochirus hispidus*, *Phycis phycis*, and *Psetta maxima maxima* in shallower waters and *Bathypterois mediterraneus* and *Coelorhynchus labiatus* at greater depths (more than 800 m).

The low frequency of some species may be explained either by their presence at the limits of their geographic distribution or by a lack of available information about them: *Bellottia apoda*, *Dentex maroccanus*, *Dysomma brevirostre*, *Epigonus constanciae*, *Heptranchias perlo*, *Lepidorhombus whiffiagonis*, *Molva molva*, *Mustelus mustelus*, *Raja circularis*, and *Raja oxyrhinchus*. The same is true for *Lepidotrigla dieuzeidei* which, however, can be misidentified because of confusion with the much more abundant *L. cavillone*. *Scorpaena stephanica*, not reported in the present inventory, can also be misidentified as the common *S. elongata*.

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Acnowledgements

This study was financed by the MEDITS-ES project (funded by the European Union). An agreement between the Instituto Español de Oceanografía and the Instituto de Ciencias del Mar made the study possible. The authors are most grateful to the scientific team on board the R/V *Cornide de Saavedra*, both those who were there occasionally and those present during the four cruises. Sergi Meseguer was in charge of the English version of this paper, and Griselda Lloris partly processed the data. Our thanks to both of them for their collaboration.

Fish diversity in the Spanish Mediterranean

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Abstract

MEDITS data files of annual trawl surveys for 1995, 1996 and 1997 were used to determine the spatial distribution of ichthyofauna diversity and analyse its changes in the Spanish Mediterranean over a three-year period. Statistical inferences were formulated concerning trends and comparisons among different depth strata and regions. Geostatistical techniques were applied for spatial extrapolation in order to estimate diversity within a wider area hypothetically occupied by the resources. Finally, a Geographical Information System (ESRI ArcView 3.0 software) was used to map the results. A clear trend towards decreasing diversity with time was apparent for this study period in the three sectors and five depth strata. With respect to depth, stratum 3 (100-200 m) had the lowest values, whereas the sectors showed no significant differences. β-diversity was calculated for the three years, confirming the hypothesis of a decreasing trend.

Introduction

A series of trawl surveys has been carried out in the Spanish Mediterranean since 1994 as part of the MEDITS (Mediterranean International Trawl Survey) programme funded by EEC-DG XIV, which is intended to improve knowledge of demersal resources in the Mediterranean. The MEDITS database was used to calculate diversity indices in the Spanish area, which was divided into three sectors: sector 111 (5° 30'W, 35° 30'N; 0° 45'E, 37° 40'N), sector 112 (1°W, 37°N; 1° 40'E, 39° 40'N) and sector 113 (0° 30'W, 39° 10'N; 4° 30'E, 42° 40'N). Depth strata were limited as follows: stratum 1 (10-50 m), stratum 2 (51-100 m), stratum 3 (101-200 m), stratum 4 (201-500 m), and stratum 5 (501-800 m).
The number of species and their relative abundance in an ecosystem at a given time can be expressed in terms of "species diversity". Several formulations have been developed to measure species diversity in a given habitat. In the present study, the Shannon-Weaver index was applied to the demersal fish community (Shannon & Weaver, 1963).

A variation of this index can be applied to differences in environmental conditions in relation to anthropogenic actions on natural systems, such as the increasing presence of pollutants (Ros & Cardell, 1991; Norse, 1993), over-exploitation of some resources (Larrañeta, 1970; Margalef, 1974; Angel, 1992; ICES, 1991), and disturbance of benthic structures by intensive trawling (McAllister, 1991; Martin *et al.*, 1995). As an indicator of the structure and state of the marine ecosystem, the importance of species diversity has been clearly stated by the Mediterranean Action Plan of the United Nations programme (Meeting of Plenipotentiaries on the Annexes to the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean, Monaco, 1996).

The study of variations in diversity along a spatial or temporal gradient or among different habitats has led to the definition of a new parameter: β-diversity (Whittaker, 1960, 1977). Several authors have developed different expressions to measure this type of variation (Magurran, 1983). All take species richness into account, either qualitatively (presence/absence) (Whittaker, 1960; Cody, 1975; Routledge, 1977; Wilson & Shmida, 1984) or quantitatively (considering abundance, such as the various similarity indices commonly used in ordination studies).

Materials and methods

The ichthyofauna diversity index was calculated and analyzed using the MEDITS database from Spanish surveys between 1995 and 1997.

The Shannon-Weaver formulation was used to calculate diversity in all trawls performed. Diversity was studied in different years, sectors and strata using the Kolmogorov-Smirnov normality test to determine its distribution. One-way ANOVA was performed for diversity distribution by strata when the variable proved to be normal. Box-Cox transformation to diversity distribution by year was conducted to improve normality and the homogeneity of variances. When results for distribution by sector were not normal, the non-parametric Kruskal-Wallis test was used for comparisons.

The β-diversity of Whittaker (1960) was calculated for the three sets of trawls in 1995, 1996, and 1997.

The spatial structure of the diversity index was modelled to obtain global evaluation, and simulation of the distribution of the variable over a hypothetical area was performed by geostatistical techniques. The continuity of the variable, as demonstrated by low coefficients of variation (see means and standard deviations in tables 1, 2 and 3), led us to select spherical variograms with a null nugget effect, whose parameters were estimated by non-linear regressions.

Finally, the representation of this model was displayed with ESRI ArcView 3.0 software, a Geographical Information System for which a series of *ad hoc* interfaces was developed and applied to raw data files.

Table 1 - Mean (X) and standard deviation (SD) for the diversity index summarising the three study years.

Years	X	SD	Z	α	Z'	α'
1995	2.7034	0.8508	1.4205	0.0354	0.6292	0.8235
1996	2.4747	0.8210	1.3771	0.0451	0.5269	0.9441
1997	2.2924	0.8681	1.2687	0.0800	0.6505	0.7912

(Z): parameter for the Kolmogorov-Smirnov normality test and its significance level (a).
(Z') and (α'): the same parameter and significance level after application of the Box-Cox transformation to the diversity index.

Table 2 - Mean (X) and standard deviation (SD) for the diversity index in the five depth strata summarising the three study years.

Strata	X	SD	Z	α
1	2.4934	1.0118	0.6509	0.7906
2	2.8089	0.7354	1.2638	0.0820
3	1.7558	0.9621	0.9200	0.3658
4	2.5272	0.7984	1.0747	0.1983
5	2.6548	0.4888	0.6700	0.7604

(Z): parameter for the Kolmogorov-Smirnov normality test and its significance level (a).

Table 3 - Mean (X) and standard deviation (SD) for the diversity index by sector summarising the three study years.

Sectors	X	SD	Z	α
111	2.4044	0.7670	1.3030	0.0670
112	2.6016	0.9010	0.8767	0.4257
113	2.4772	0.8924	1.8069	0.0029

(Z): parameter for the Kolmogorov-Smirnov normality test and its significance level (a).

Results

Changes in diversity from 1995 to 1997

The normality test of Kolmogrov-Smirnov proved significant for 1995 and 1996, but not 1997. After Box-Cox transformation, normalization was achieved with the variable for the three years considered (table 1). ANOVA provided a highly significant F value of 8.06 (table 4), indicating differences in diversity over the years.

Table 4 - One-way ANOVA for the diversity index after Box-Cox transformation, with years as the classification factor.

	DF	Sum of squares	Mean squares	F ratio	F prob.
Between groups	2	54.0357	27.0178	8.0639	0.0004
Within groups	309	1035.2974	3.3505		
Total	311	1089.3330			

Multiple comparisons by the Bonferroni test (Dunn, 1961) showed significant differences between the highest diversity year, 1995, and the two following years, with a decreasing trend in the diversity index from 1995 to 1997 (fig. 1a.). The values for the β-diversity parameter were in agreement with this trend (table 5).

Table 5 - β-diversity of Whittaker (1960) for the three study years.

Years	**β- diversity**
1995	6.06
1996	6.60
1997	6.97

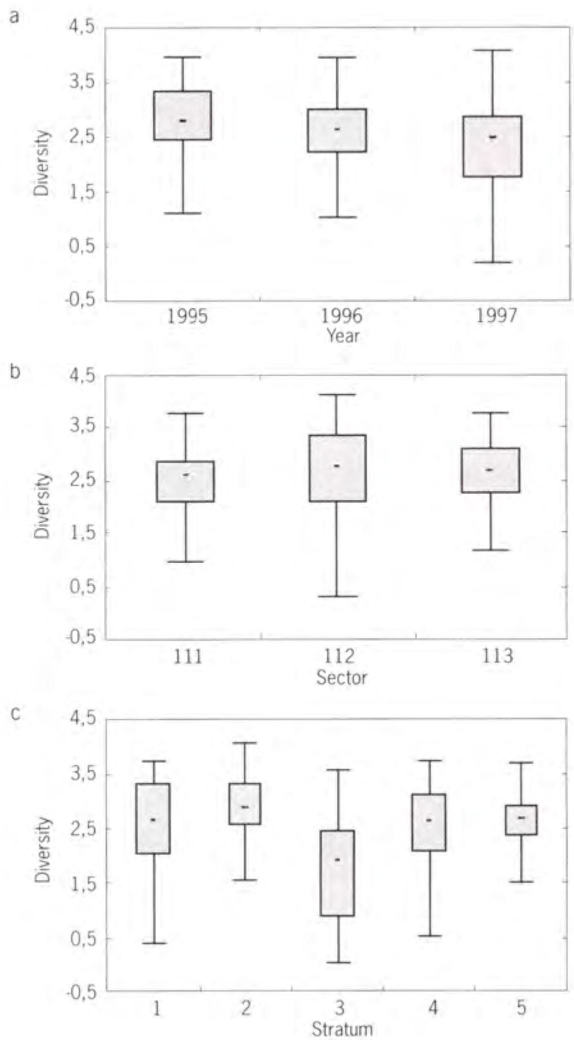


Figure 1
Diversity distribution. Boxplot of means by year (a); sector (b) and stratum (c).

An important factor to be considered at that point is the increasing abundance of some species, mainly *Micromesistius poutassou* which progressed from 12% of the total number of individuals in 1995 to 52% in 1997 (unpublished MEDITS annual reports, 1995, 1996 and 1997).

Diversity behaviour in depth strata

Diversity index distribution in the five depth strata fitted normality (table 2). One-way ANOVA showed significant differences among strata (table 6). The Bonferroni multiple comparisons test indicated that stratum 3 (100-200 m) had the lowest diversity, while the other four strata appeared to be similar (fig. 1c). In fact, stratum 3 contained the maximum number of individuals of the dominant species, *Capros aper* in 1995 and *Micromesistius poutassou* in 1996 and 1997 (unpublished MEDITS annual reports, 1995, 1996 and 1997).

Table 6 - One-way ANOVA for the diversity index, with strata as the classification factor.

	DF	Sum of squares	Mean squares	F ratio	F prob.
Between groups	4	42.0145	10.5036	17.1265	0.0000
Within groups	307	188.2817	0.6133		
Total	311	230.2962			

Diversity behaviour in sectors

The Spanish Mediterranean includes sectors 111, 112 and 113. The Kolmogorov-Smirnov test showed that diversity was not distributed normally among sectors and that the value of α (0.0029) in sector 113 (table 3) was of special significance. In view of this situation, a comparison among sectors was performed using the Kruskal-Wallis rank test. The results (table 7) indicate that the diversity index in the Spanish Mediterranean does not show significant differences among sectors (fig. 1b).

Table 7 - Kruskal-Wallis mean rank test for diversity by sector.

Sectors	Cases	Mean rank	χ^2 square	DF	Significance
111	93	141.89	4.4909	2	0.1059
112	95	169.73			
113	124	157.32			

Comparison of the diversity index by year within strata

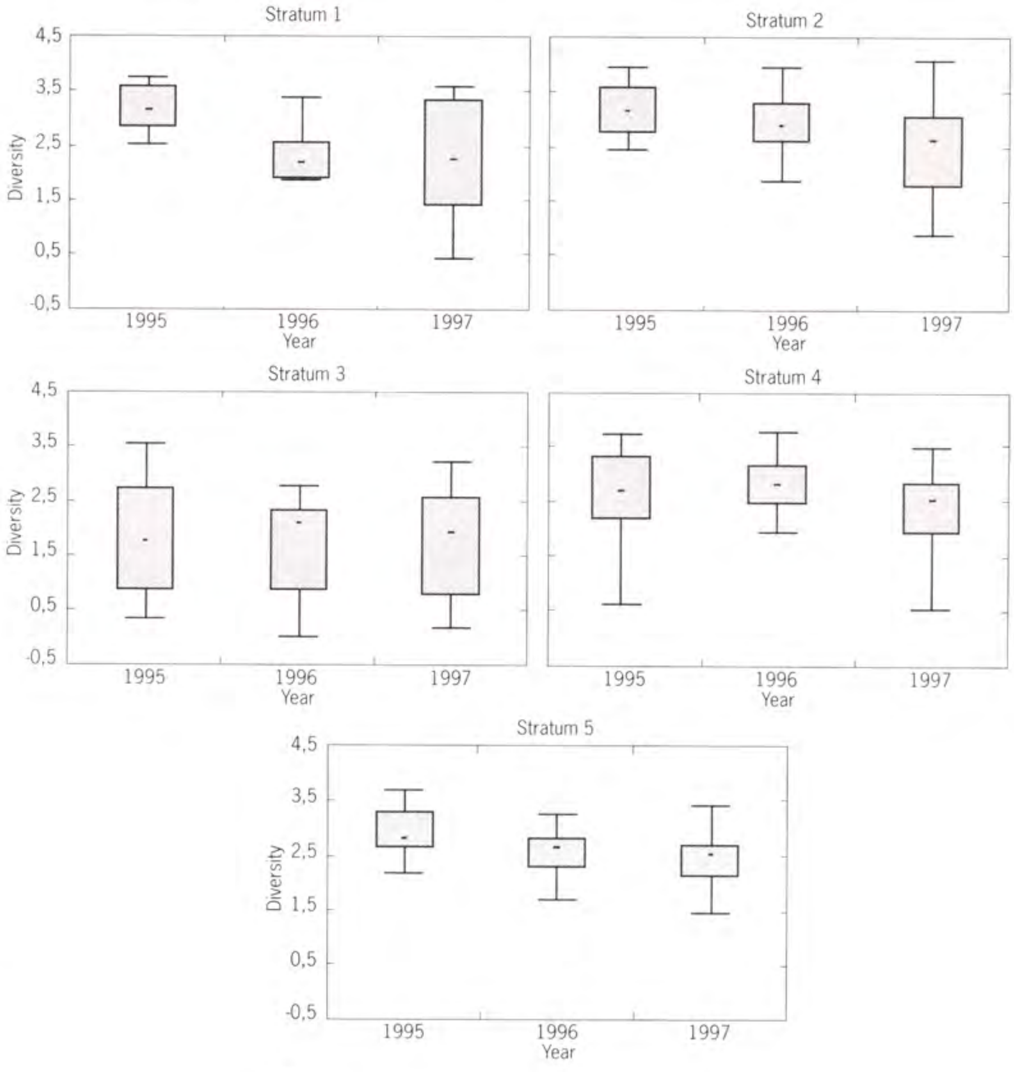
A decreasing trend in the diversity index was observed over the three years. An analysis of this trend within each depth stratum showed a clear decrease in the first two (0-100 m) and the last one (> 500 m), whereas the trend was not apparent in the middle strata (100-500 m) (table 8 and fig. 2). In stratum 3, the diversity values were low and very similar during the three years, probably because of the change in orography from shelf to slope and the presence of great numbers of individuals of the dominant species, *Micromesistius poutassou* and *Capros aper*. In stratum 4, there was an increase in diversity in 1996, contrary to the general trend, although some trawls also showed very low diversity, with large numbers of individuals for dominant species.

Table 8 - One-way ANOVA for comparison of means during the three-year study performed in the five depth strata.

Strata	1995	1996	1997	C	α	F	α
1	3.1678	2.0983	2.2419	0.4929	0.343	3.56	0.044
2	3.0468	2.8583	2.5216	0.4622	0.112	4.36	0.016
3	1.8599	1.6576	1.7393	0.3831	0.845	0.21	0.813
4	2.5846	2.6681	2.3111	0.3634	0.999	1.25	0.293
5	2.9259	2.5426	2.4767	0.4230	0.447	6.10	0.004

C (for the Cochran test): parameter used to assess the homogeneity of variances and its significance level (α); F: ANOVA and its significance level (α).

Figure 2
Diversity distribution in depth during the three years. Boxplots of diversity means in the five strata.



Modelling the spatial distribution of the diversity index during the period 1995-1997

Geostatistical techniques were applied to the study of the spatial distribution of diversity. As previously stated, this global index showed moderate ranges, variances and coefficients of variation. On the basis of these premises, spatial distribution was modelled using spherical variograms with a null nugget effect. Sill and range were estimated by non-linear regression (table 9).

Table 9 - Non-linear regression of sill (S) and range (R) for the kriging diversity index.

Year	S	R
1995	0.879	7.382
1996	0.744	9.509
1997	0.683	7.915

Since the duration of the longer hauls was 1 hour at a speed of 2 knots, it seemed reasonable to use 1 square mile cells to perform kriging. The global results of this simulation showed a mean diversity of 2.4450 bytes/individual, and a standard deviation of 0.7895. The slight differences between kriged and sampled values can be explained by the aggregative nature of diversity itself.

Finally, this kriging simulation (figures 3, 4 and 5) for the three years covered by the study clearly visualizes the analytically detected decreasing trend.

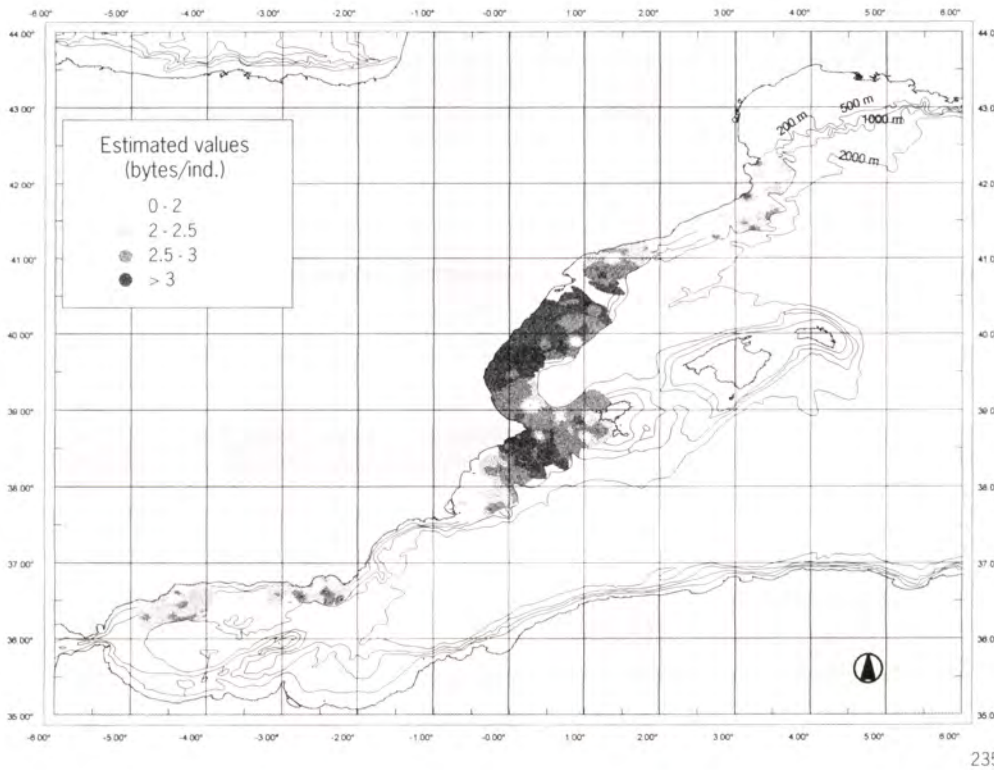


Figure 3
Results for kriging diversity values (bytes/individual) relative to the total Spanish Mediterranean area in 1995.

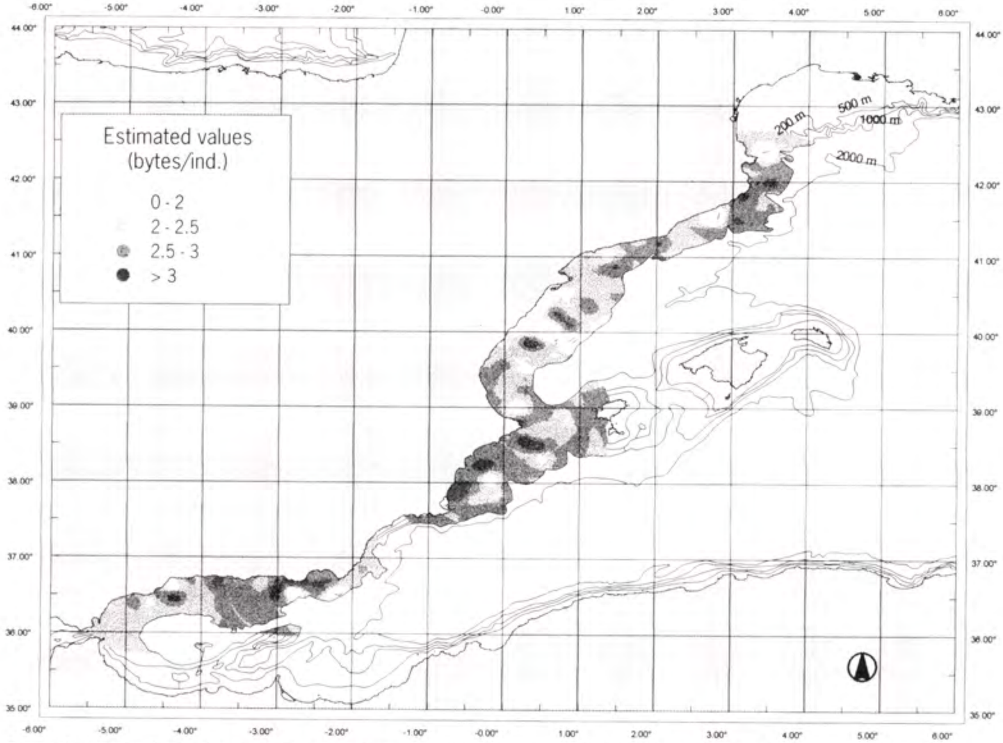


Figure 4 - Results for kriging diversity values (bytes/individual) relative to the total Spanish Mediterranean area in 1996.

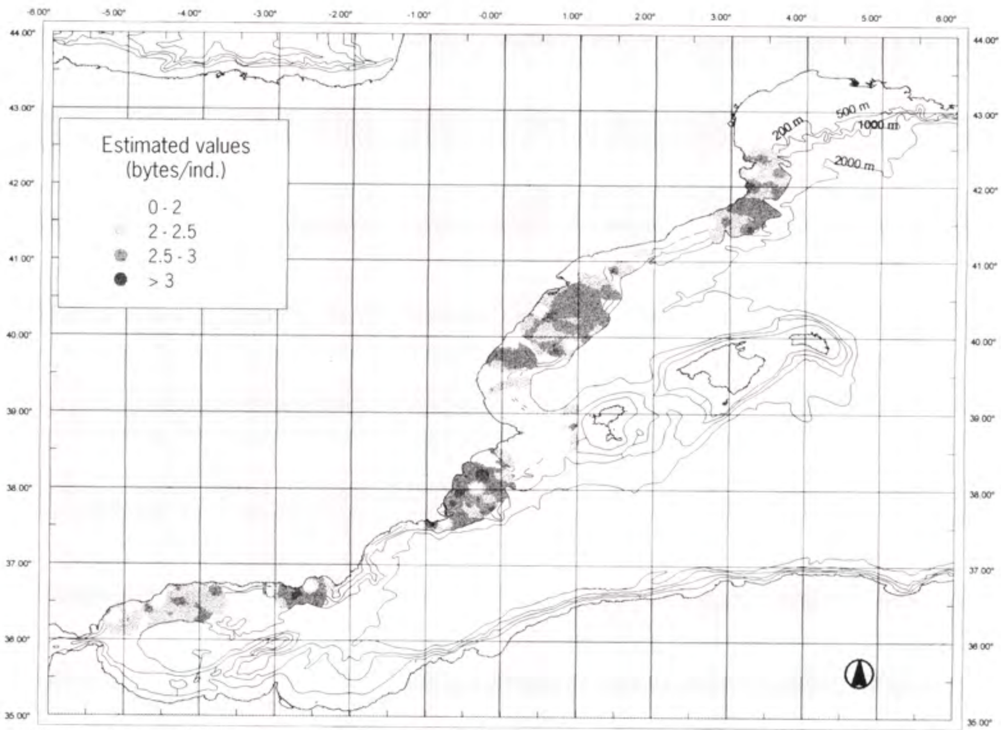


Figure 5 - Results for kriging diversity values (bytes/individual) relative to the total Spanish Mediterranean area in 1997.

Conclusion

Demersal ichthyofauna, as studied from MEDITS trawl surveys in the Spanish Mediterranean during the period 1995-1997, showed relatively high diversity values, with 2.45 bytes/individual. Average and moderate variability were confirmed by the standard deviation of 0.79 and the coefficient of variation of 0.34. There was a decreasing trend throughout the study period, which was clearly apparent in the first two strata (≤50 m and 51-100 m) and in the last one (>500 m), but not in the middle strata (101-200 m and 201-500 m). No differences in the diversity index were observed for the three sectors included in the Spanish Mediterranean region. Regarding strata, significant differences in diversity occurred between stratum 3, with the lowest values, and the other strata. In this stratum, the abundance of dominant species increased throughout the study period.
Geostatistical modelling of the diversity index provided coherent results for the sampled data, and kriging allowed visualization of the analytical determinations.

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Réalisation, mise en page : XLC (02 98 30 50 07)

Achevé d'imprimer sur les presses de Cloître Imprimeurs

ISBN 2-84433-039-8/Dépôt légal 2e trimestre 2000
ISSN 0761-3962

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Demersal resources in the Mediterranean

In 1993, the European commission incited the scientific community to initiate a joint research programme to improve the knowledge of demersal resources in the Mediterranean by bottom trawl surveys. The symposium held in Pisa, March 1998, made a general survey of scientific advances obtained during the first three years of the ensuing international programme, enriched with experiments from other areas.

Keywords: Mediterranean, demersal resources, bottom trawl surveys, stock assessment.

Ressources halieutiques en Méditerranée

En 1993, la Commission européenne a incité la communauté scientifique à lancer un programme de recherche commun basé sur des campagnes de chalutage de fond, pour améliorer les connaissances sur les ressources démersales en Méditerranée. Le symposium qui s'est tenu à Pise en mars 1998 a fait un tour d'horizon des principaux résultats scientifiques acquis par le programme international ainsi développé, enrichi d'expériences issues d'autres régions.

Mots-clés : Méditerranée, ressources démersales, chalutage de fond, évaluation de stocks.

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ISSN 0761-3962
ISBN 2-84433-039-8

240 F - 36,59 €

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