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## Geographical information system (GIS) applied to fisheries data: The case of Italian demersal resources

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**SUMMARY** - A project funded by the European Commission to produce charts for the distribution of demersal fish resources has been the occasion to implement the first nucleus of a GIS (Geographical Information System) of the fisheries resources in the Italian seas. The aim of the system is to structure and manage both geographic and alphanumeric data to allow a high degree of diversification in the analyses. This paper presents the process of implementation of the centralized system together with the basic interpolation analyses used to produce the charts of the distribution of ten target species.

**Key words:** Geographical Information Systems, demersal resources, fisheries, interpolation, cartography.

**RESUME** - "Un système d'information géographique (SIG) appliqué aux données des pêcheries : Le cas des ressources démersales italiennes". Un projet financé par la Commission Européenne pour élaborer des cartes de distribution des ressources halieutiques démersales a constitué l'occasion d'appliquer le premier noyau d'un SIG aux ressources halieutiques des mers italiennes. Le but de ce système est de structurer et de gérer des données à la fois géographiques et alphanumériques pour permettre un haut degré de diversification dans les analyses. Cet article présente le processus de mise en oeuvre du système centralisé ainsi que les analyses de base pour l'interpolation qui ont été utilisées pour élaborer les cartes de distribution de dix espèces cibles.

**Mots-clés :** Systèmes d'Information Géographique, ressources démersales, pêcheries, interpolation, cartographie.

### Introduction

The representation of faunistic data on charts illustrating their spatial distribution over large areas is becoming increasingly important for naturalistic and exploitation management purposes.

Since 1982, the Italian government has provided financial support for scientific and technical research on biological resources evaluation to improve marine fisheries management. In this framework, national experimental trawl surveys started in 1984 on a seasonal basis and are still being carried out along the Italian coasts (Relini, 1985; Relini and Piccinetti, 1994).

One of the goals of the collection of these data has been to organize a national data bank, from which information for various purposes can be taken. The first application of this data gathering was the production of maps of the distribution and abundance of the 10 main Italian demersal species. This application, carried out with the financial support of the European Commission and the Italian Resources Ministry, provided the initial incentive to move the data bank towards a GIS structure.

Many important applications of GIS have proven of great interest in natural resources management in the past few years (Miller, 1994), though few of them concern fisheries data (Kapetsky *et al.*, 1987). This is particularly true in the Mediterranean where the risk of a possible increase in overfished areas could be prevented through a better management of the large amount of existing scientific data (Caddy, 1996).

The ability of GIS to manage and analyse large amounts of data based on their geographic position has made it the perfect choice to deal with the big amount of data already collected from all over Italy.

## Materials and methods

### Data sets

The basic data used in the analysis presented in this paper are the result of the experimental trawl surveys carried out in the years 1985 to 1987.

All Italian seas (except part of the Ionian Sea east of Sicily) were considered; 15 Operative Units including more than 120 researchers and technicians were involved with 17 motor-trawlers (Relini, 1985).

Stratified random sampling was chosen after the zones had been assigned to the Operative Units (OUs). This fact accounted for the heterogeneity of sampling density. Every zone was subdivided into strata according to the bathymetric lines, since other information concerning biotic communities, the kind of bottoms and the density of fish populations were not available for almost any area.

The following five main divisions were established: from 0 to 50 metres, from 50 to 100 metres, from 100 to 200 metres, from 200 to 450 metres and from 450 to 700 metres.

Each stratum was subdivided into rectangular areas about 3 miles long, corresponding to one hour trawling. The randomization was performed for each of the two seasonal cruises. At all depths, the haul lasted one hour.

Two periods per year (summer: from 15 August to 15 September and spring: from 15 March to 15 April) were chosen.

An exhaustive study of the biological aspects of the following ten target species was planned: *Merluccius merluccius*; *Mullus barbatus*; *Micromesistius poutassou*; *Phycis blennoides*; *Parapenaeus longirostris*; *Aristomorpha foliacea*; *Aristeus antennatus*; *Nephrops norvegicus*; *Eledone cirrhosa*; *Octopus vulgaris*.

All fractions of the catch were weighed; in particular all samples of target species were frozen and sent to the laboratories where all individuals were measured, weighed and sexed. Gonads and otoliths were then taken for further observation. As mentioned above, all data concerning catch, number and weight of target species referred or were standardized to one-hour periods.

All the collected data relevant to 3,044 hauls were utilized to organize a project on Italian demersal resources mapping.

In order to obtain the geographic parameters needed for the subsequent analysis, data relative to the depths and the coastline of Italian seas had to be acquired. Topographic information was taken from the nautical charts of the Istituto Idrografico of the Italian Navy. We acquired a total of 20 charts; of these, nineteen were at the scale 1:250,000 and one was at the scale 1:1,700,000. The latter was used to provide a general overview of the study area.

### Data bank

The system is based on ARC/INFO (ESRI, 1991) as its main GIS package. Along with ARC/INFO (both on PC and on UNIX workstation), we use MIPS (Microimages, 1991) as image processing software.

To allow for total compatibility with all collaborating Institutions, all database management is 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, analysed data and structured and managed all geographic data. Conversion programmes ensured data flow and consistency between the two platforms.

Despite the risk of data redundancy and inconsistency, experience matured during wide-ranging projects involving various Operative Units (Boitani *et al.*, 1993) suggested setting up the data bank on

the two different hardware platforms. In fact, use of the PC platform ensures compatibility among all participants, allows for use of less expensive computers and less specialized personnel for data management and control, and avoids overloading the UNIX platform, already burdened with analysis, with the alphanumeric data management.

## Data homogenization and control

Data were checked for consistency, corrected and later converted into an ARC/INFO compatible format.

The first step in setting up a homogeneous data structure was an assessment of the data structures existing in the OUs. In fact, each Operative Unit had worked with its own data structures and different software packages, generally containing more or less the same information, but ordered in a different manner, depending on the priority interests of each OU.

Based on the result of this first screening, the following step was to create a data structure that could contain the maximum of information needed with the minimum of conversion. We chose an XBase archive format, a standard which is used by almost all OUs. This format, being a de facto standard, is recognized by most PC applications.

As for the data relative to hauls, OUs were asked to provide the following information for the years 1985, 1986 and 1987: (i) haul identification (distinctive to each OU); (ii) date of haul; (iii) haul geographic coordinates (lat. and long. E.D.50); (iv) haul depth in metres; and (v) haul duration in minutes.

Total commercial yield for the ten target species was requested.

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 are contained in a series of files (one per species), which also contain references to the hauls in which the species were caught, thus allowing for cross-referencing.

To simplify data acquisition, OUs were allowed to define their own haul identification codes used to link haul data to length frequency distributions. Therefore, once the data were received by the collection centre, unique haul codes were created and files coming from the various Operative Units merged.

The data provided by the Operative Units and relative to the 3,044 hauls were first put through a numerical control for errors (typos, transfer and reading errors), which were then corrected. General archives containing the data of all OUs were then set up.

The archives were checked for less obvious errors by means of a series of computer routines that cross-checked the files highlighting discrepancies. Cross-checks between haul data and data on length frequency distribution revealed errors such as hauls with ponderal yields for some species but without corresponding length frequency distributions, or mean individual weights above the species' upper weight limit.

Checks were also carried out on the coordinates provided by the OUs. In addition to an initial screening to identify data beyond the study area's geographic limits, the haul points were superimposed on Italian nautical charts. In order to carry out this double check, the geographic coordinates provided by the UOs had to be converted into a Lambert conical projection using the procedure described later in this paper so that they could be compared to the cartography already stored in the computer system of the University of Rome's Dept. of Animal and Human Biology.

Errors and oversights were tabulated and plotted for each OU and returned to OUs for correction. On the basis of the charts corrected by the OUs, the new points were entered in the system by manual digitizing.

One further, definitive check was carried out on alphanumeric data while corrections from the UOs were being entered into the final data bank files. Some discrepancies were discovered even at this stage and corrected with the collaboration of the OUs concerned.

### Standardization

Due to the differences (vessels of different tonnage and engine power, nets of different sizes with different mesh size) in the boats used to conduct the surveys in the different areas, data had to be standardized.

As stated by Auteri *et al.* (1988), Fiorentini and Cosimi (1987), and Fiorentini and Giorgetti (1985), the characteristics of each fishing vessel and relative nets can be described by six parameters: gross tonnage, nominal engine output (HP), area of otters, sweep length, floatline length and the circumference of the open net (measured by the number of meshes at the opening multiplied by mesh size).

For our purposes, these parameters were correlated to relative average yield per hour.

The standardization method proposed by Auteri *et al.* (1988) is based on analysis of the correlation between the various characteristics of the vessels and of the nets (independent variable) and the catches (dependent variable). The authors found higher correlation for some net parameters, such as groundrope and floatline length, sweep length and engine output than for tonnage and other net parameters such as opening size and otters area.

A reference vessel also had to be established with characteristics based on an adjusted mean obtained from the vessels actually used by the OUs in the areas in the periods considered. The following formula was used for calculation of the standardization index (Auteri *et al.*, 1988):

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

where

- Cst = standardized catch;
- Cre = real catch;
- LS = length of floatline;
- LSC = length of floatline plus sweeps;
- Hp = nominal engine output.

Standardization coefficients were calculated for all operative units involved in the study (Table 1).

The coefficients calculated were applied, per OU, to the overall yield data and the data for the ten target species. They were also applied to the target species frequency distribution, giving comparable values for yield and size distribution, which were then used in subsequent analysis.

Table 1. Standadization coefficient per OU

OU	1	2	3	4	5	6	7	8
SC	1.1	0.9	1.2	1.3	1.2	1.1	1.2	1.1
OU	9	10	11	12	13	14	15	
SC	1.1	1.0	1.4	1.0	1.0	1.7	0.6	

### Implementation of the GIS

A planar reference system has to be used to obtain data that can be used and analysed within a GIS. To that end, we chose a projection system to which the scanned maps could be georeferenced.

As our original data sets were gathered from nautical charts in Mercator projection, we decided that the entire geographical database would be referenced to the Mercator projection.

Consequently, the data supplied by the OUs expressed in geographic coordinates were exported from the alphanumeric data bank into a file in text format suitable for the ARC/INFO geographic projection (PROJECT) conversion routine. The file obtained was used to generate the coverage (digital analogue of a map) of the haul points in ARC/INFO format. Each point was labelled with the haul identification code established during structuring of the data bank, so that it could be associated with all the information relative to it in the alphanumeric data bank.

## Acquisition of basic cartography

The first stage of acquisition of cartographic data involved scanning of the nautical charts at both scales (1:250,000 and 1:1,700,000). Maps were scanned at 200 dpi and 256 levels of grey. The files generated were in TIFF format and had an average size of 65 Mbytes.

Scanning, especially with a tractor scanner, such as the one used for this project, is the most delicate stage of the procedure, as it involves precise calibration of the hardware to avoid distortions that cannot be compensated by georeferencing. Even with the appropriate calibration of the scanner, the resulting raster images produced had to be rectified to obtain data with characteristics of linearity suitable for cartographic acquisition.

During georeferencing, each pixel (picture element) of the image is associated to its correct position in space. The procedure is extremely simple but relatively lengthy. To increase the speed of the entire process, empirically we found that a preliminary rotation of the charts that extended horizontally by 90° greatly enhanced the performance of the warping algorithm.

Control points were taken at the intersections of all parallels and meridians and between them and the edge of the chart as well as at the four corners of the charts. Thus an average of 50 control points were defined for each chart. Once the control points were defined, a piecewise linear fit warping algorithm was used to assign the correct position in space to each point of the image. The piecewise linear fit algorithm ensures exact correspondence between each control point and the coordinates assigned (Wolberg, 1994).

As a general georeferencing procedure, it was decided to maintain the original projection parameters for each chart, postponing homogenization of coordinates until merging of vector data taken from the raster images. Each chart was then georeferenced to the Mercator projection using the following projection parameters: the true scale parallel taken from the chart's legend and the chart's central meridian as the x coordinates origin.

The entire georeferencing process was carried out using the MIPS programme. This package is more complete than ARC/INFO as concerns image processing and guarantees an easy flow of data towards the latter.

Once georeferenced, the images were imported in the ARC/INFO GRID format for the next phase of acquisition of vector information.

Acquisition of cartographic data in raster form not only made it possible to obtain a complete reference base at low cost, but also allowed for extraction of vector data by means of hand digitalization using a video terminal.

This choice presents two advantages. The first is a savings in acquisition time, as we have three video terminals and only one digitiser in our computing centre. The second is that video digitalization allows for enlargement of the image to the point where individual pixels can be seen, thus offering a degree of accuracy not obtainable with digitisers.

Two ARC/INFO coverages were extracted from each chart: a line and a point coverage. The former included bathymetric curves and coastlines and the latter included depth points.

At this stage, a numeric code corresponding to depth was associated to each element acquired.

The overall process of vectorialization was the most lengthy procedure and occupied the greatest number of operators who, due to the stressing activity involved, took turns at the video terminal to guarantee an adequate quality standard.

After an initial check for and correction of errors, the coverages deriving from video digitalization were projected to a common projection. We chose a Mercator projection, using the true scale parallel (lat. 38° 00' 00") of the chart of the Italian seas "Carta dei Mari d'Italia" and the central meridian (14° 00' 00") of the same chart as projection parameters.

Once all the coverages had been brought into the same reference system, they were clipped to eliminate overlapping areas (for both point and line coverages). Adjacent charts provided for considerable overlap of data in the final coverages. This ensured greater precision during merging of the coverages deriving from digitalization, as it was possible to locate the cutting edge of the clipping polygon in the area with the least errors (e.g., the central area of the chart, the one with the highest degree of control during the warping phase).

Merging of the trimmed maps produced one map at the national level for depth points and one for bathymetric lines.

As already mentioned, acquisition of bathymetric data was dictated by the need to provide a framework for the charts generated and to obtain fundamental data for subsequent stages of analysis. In particular, the system required the bathymetric limits of the species so that the quality of interpolation could be improved. Those limits were interpolated from the digital terrain model (DTM) of the sea bottom generated from bathymetric lines and depth points acquired from cartography.

We first used ARC/INFO's TIN programme. TIN constructs a triangulation model from data that are not equidistant, such as the bathymetric data taken from traditional charts. Starting out from points that may either be taken from depth points or from an automatic resembling of the points that define a bathymetric curve, the system develops a model using the Delaunay triangulation method, which ensures that triangles are formed with points that are closer to each other than to any other point of the model. This guarantees the best possible representation of the area being analysed compatible with the original data (Laurini and Thompson, 1992; Bailey and Gatrell, 1995).

The DTM was then obtained from the triangulation model by converting the non equidistant structure into a regular one (lattice). Finally, the depths defining the limits of the species' presence were interpolated from the DTM. In order to make interpolation sufficiently smooth, the resolution of the original DTM was increased up to a grid with 250 m cell size.

A coverage of the depth limits of the species' presence was generated for each species.

The last layer inserted into the information system was relative to untrawlable areas. This map was acquired using a digitiser from the charts that were sent to the OUs for the correction of the haul points together with the request to indicate untrawlable areas. Although these draft charts were in 1:250,000 scale, the inaccuracy with which areas were sketched in brought the final level of information down to that of a chart with a 1:500,000 scale, making this layer the most inaccurate of the data bank.

## **Analyses and results**

The objective was to produce maps showing the distribution of Italian demersal fisheries resources. Therefore, starting out from the point data provided by the experimental trawl surveys, yield data and distribution had to be extrapolated at a national level. This was done using interpolation algorithms which can reconstruct a surface throughout a study area from a number of known points.

## Interpolation of yield data

There were basically two objectives to this stage: (i) to obtain yield surfaces to be used for the analysis of seasonal concentrations; and (ii) to provide a homogeneous national map for each of the ten target species.

The choice of analysis method was determined by the need to produce homogeneous data at national level and, therefore, to consider areas with diverse experimental data densities.

Several methodologies were considered; tests were carried out both with linear deterministic methods and with geostatistical methods: ordinary and universal kriging, with and without external drifts (Bruno and Raspa, 1993; Cressie, 1993). In all cases, however, the irregular nature of the area under study and the non-homogeneous distribution of observations points caused anomalous behaviour. In particular, the linear deterministic method, in which no structural correlation among the various observation points is taken into account, proved to be unsuitable for providing a homogeneous picture in areas where coverage of sample points was low or in transition areas (high to low density).

The first tests carried out with the geostatistical method, which is based on the regionalized variable theory (Borough, 1986), produced interesting results. More precisely, yield data revealed the presence of a drift essentially linked to depth. A tests was then carried out on geostatistical interpolation methods that make use of the distribution of an auxiliary variable to describe the trend of drift in data (Bruno and Raspa, 1993). This method proved to be more suitable for modelling the distribution of fish species, but the large amount of data to be analysed and the limitations of the software that implements the algorithm made its use impossible.

It was then decided to divide the study area into subzones in an attempt to obtain a sufficiently homogeneous trend in bathymetric variation that could be describable with universal kriging polynomial functions.

Seven macro-zones were identified: the Ligurian and northern Tyrrhenian Sea, the central Tyrrhenian, the southern Tyrrhenian, the Sicilian Channel, the Ionian Sea, the Adriatic Sea and Sardinia. Further local divisions were sometimes made to facilitate interpolation. Nevertheless, in a number of subzones there were large areas in which the interpolating functions showed low control because of the total lack or low density of haul points. In this situation, the use of polynomial functions to model the drift generated anomalous peaks in correspondence to low control areas. This was even more evident when polynomials of a degree higher than the first were used.

Therefore, a mixed method was adopted. At first an interpolation was carried out by means of universal kriging with the drift described by a linear function. A visual analysis of the result was used to evidence areas in which the kriging had produced inconsistent results (e.g., areas with unusual over or under estimates in yield characterized by high variances of the estimate). These areas were either masked out of the resulting interpolation and considered as data deficient areas or homogenized to the nearest consistent data, depending on a subjective evaluation of the quantity and quality of the original data points. To smooth the resulting representation, this first interpolation and its following adjustment was analysed by means of a filtering technique capable of extracting the most relevant data points. These were merged again with the original data points and interpolated a second time by means of a linear interpolator.

## Identification of nursery areas

In addition to the problems of interpolation outlined above, the identification of concentration of juveniles posed the problem of providing an operative definition of the term nursery on which to base choices during subsequent analysis. Nursery was defined as an area with a statistically significant concentration of individuals of size inferior to certain dimensions. On the basis of this definition, a threshold sizes for the various species were established (Table 2).

Within each haul, the number of individuals belonging to length classes inferior to the threshold given were added and the resulting value was used as third dimension values to interpolate a numeric

yield surface. Interpolation was performed by means of universal kriging algorithm with a linear function describing the drift.

Table 2. Threshold size used to distinguish juveniles from adults

Species	Length	Method
<i>Merluccius merluccius</i>	12 cm	Total length
<i>Mullus barbatus</i>	10 cm	Total length
<i>Micromesistius poutassou</i>	12 cm	Total length
<i>Phycis blennoides</i>	12 cm	Total length
<i>Parapenaeus longirostris</i>	2 cm	Carapax length
<i>Aristomorpha foliacea</i>	2 cm	Carapax length
<i>Aristeus antennatus</i>	2 cm	Carapax length
<i>Nephrops norvegicus</i>	2 cm	Carapax length
<i>Eledone cirrhosa</i>	4 cm	Dorsal mantle length
<i>Octopus vulgaris</i>	5 cm	Dorsal mantle length

Taking the number of individuals belonging to a certain length class present at each point as an index of the use of the space by individuals of that length class, we can determine the point at which the number of individuals indicates a transition from a uniform use of space to a selective use. We chose this value to represent the limit of the nursery area as defined in the preceding paragraph and it can be interpolated from the surface obtained by kriging.

The numerical value identifying the concentration areas was determined by comparing the ordered cumulative distribution of the probability of use observed (the number of individuals at each point divided by the total number of individuals) with the ordered cumulative distribution of probability of uniform use (total number of individuals divided by the total number of points) (Samuel *et al.*, 1985; Sokal and Rohlf, 1995). Any duplicate coordinate was relocated within a distance of 250 meters from its origin to assure that no two points share the same coordinate.

This method of identifying areas of preferential use has the advantage that it can be statistically tested by means of the one-sided Kolmogorov-Smirnov goodness-of-fit procedure (Daniel, 1978).

The two seasons were analysed both separately and together. All values obtained proved to be highly significant ( $P < 0.01$ ), except for *M. merluccius* and *P. longirostris*, for which the annual analysis was found to be not significant. Nevertheless, in the case of *M. merluccius*, analyses carried out on the two separate seasons were again highly significant, while the levels of significance for *P. longirostris* remained rather low. For this species the most likely threshold value was nevertheless established on the basis of distribution data found in literature.

Although we are not aware of applications of this method in this specific field, the literature provides examples of its application in studies on habitat-use and use of space by terrestrial vertebrates (Samuel *et al.*, 1985).

## Generation of charts

The objective of the final stage of the project was to plot charts of the foregoing data which would allow for facilitated reading of analysis results.

As basic data were acquired from charts at 1:250,000 scale, it was considered convenient to generate charts at the same scale. Yet, in order to make charts more manageable, the A1 format was chosen rather than the usual A0 format of the official charts of the Istituto Idrografico of the Italian Navy. In this way, the entire study area was covered by 22 charts rather than the original 19 (Fig. 1).

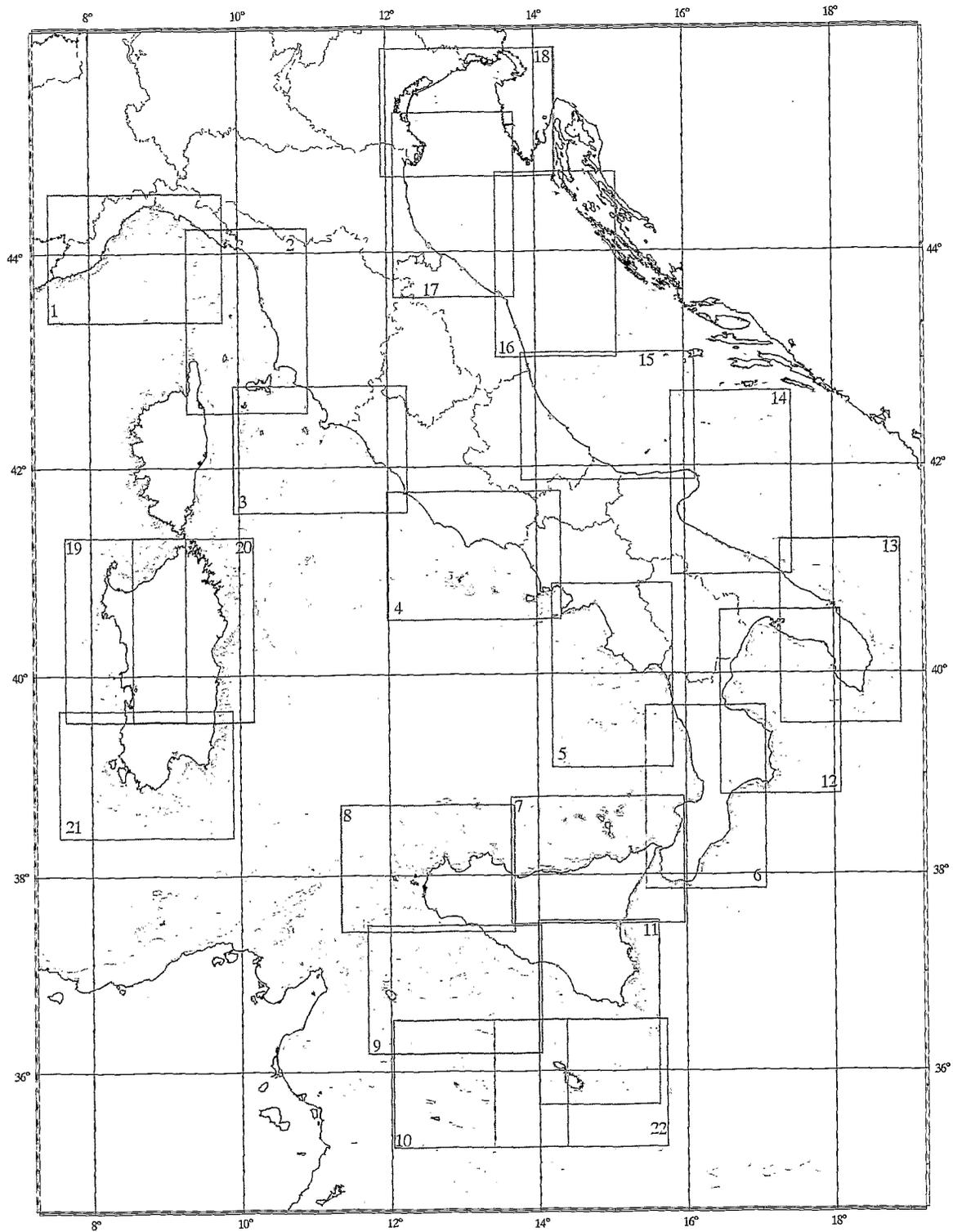


Fig. 1. Index map of the distribution charts produced.

The topographical surroundings of the study area also had to be reconstructed to allow for rapid localization. To that end, simplified orographic information represented by 200 m contour lines was interpolated from the DTM of Italy available in the GIS database of the Dept. of Animal and Human Biology; road and railway networks were taken from the digital coverage of the Italian Touring Club maps, and the perimeters of urban centres were provided by the Italian electric utility (ENEL). This information provided an adequate setting for the study area.

We decided to keep the same projection parameters throughout the national territory: (i) Mercator projection; (ii) true scale parallel 38° 00' 00"; and (iii) x origin meridian 14° 00' 00".

Although this caused some distortion in the charts furthest from the reference parallel, maintaining the same projection facilitates possible piecing together of charts.

The same colour code was used to indicate the yield of all species. The colour scale, made up of 12 tones ranging from light to dark blue, was subdivided per species into logarithmic hourly yield classes. The use of a logarithmic subdivision of classes allowed for a better representation of the areas stretching the representation of area with lower yields.

The boundaries of nursery areas are marked with a hachured red line. The depth limits of the species' presence are marked with a fine hachured black line, while the untrawlable areas are shown with a dense lattice and the area lacking haul points are shown with diagonal lines.

As a result of all the previous activities, separate seasonal charts were produced for each species, for a total of 44 charts per species and an overall total of 440 charts (Figs 2 and 3). One additional national chart illustrating ports, haul points and basic general statistical data originating from the Italian statistical agency (ISTAT) was also produced.

## Conclusion

During the three years of the project two major goals were achieved:

(i) The first nucleus of a possible GIS for the fisheries resources of the Italian seas was established.

(ii) A methodology, which can be used for other species and/or for different years to represent the distribution fisheries resources was defined.

Considering that the main objective of the research program was simply to produce the charts of the available fisheries resources, it can be said that our results have gone far behind the original goal.

This was achieved through full and accurate use of all available facilities. First of all, we had a GIS lab functioning within the Dept. of Animal and Human Biology of the University of Rome "La Sapienza". Then we managed to use the funds of the project to create a working team whose interest in the use of the GIS tool for the assessment of fisheries resources goes beyond the simple production of distribution charts.

As regards setting up and managing a database, we gained adequate experience through a strictly experimental procedure based on trial and error. We recommend great caution in some crucial stages of the implementation, such as quality control of the original data provided by the OUs and the acquisition of the raster base maps. The former can turn out to be the worst bottleneck of the entire process due to the continuous need to obtain feedback and corrections from the OUs, while the latter is the basic step for the acquisition of the data sets needed to do even the most elementary analyses (most of the charts had to be scanned at least two times to obtain an adequate overall quality of readability and to reduce distortion).

Finally, we have only reported the analyses that were functional to the aims of the project. Of these, the methodology used for interpolation of yields produced results in accordance with what was expected by the different OUs. The same cannot be said for the identification of nursery areas, where the statistical analysis conducted on a single data set including all Italian seas, has probably introduced a bias in the estimate, increasing the size of the nursery in areas of particularly high concentration of the species and decreasing them or even eliminating them in areas of low density.

Recently (Corsi and Ardizzone, in press) some enhancements to this method have been made by: (i) increasing the reliability of the statistical test through the use a modified Kolmogorov-Smirnov test according to the suggestions of Lilliefors (1967), Harter *et al.* (1984) and Khamis (1992); and (ii) partitioning the area into smaller portions.

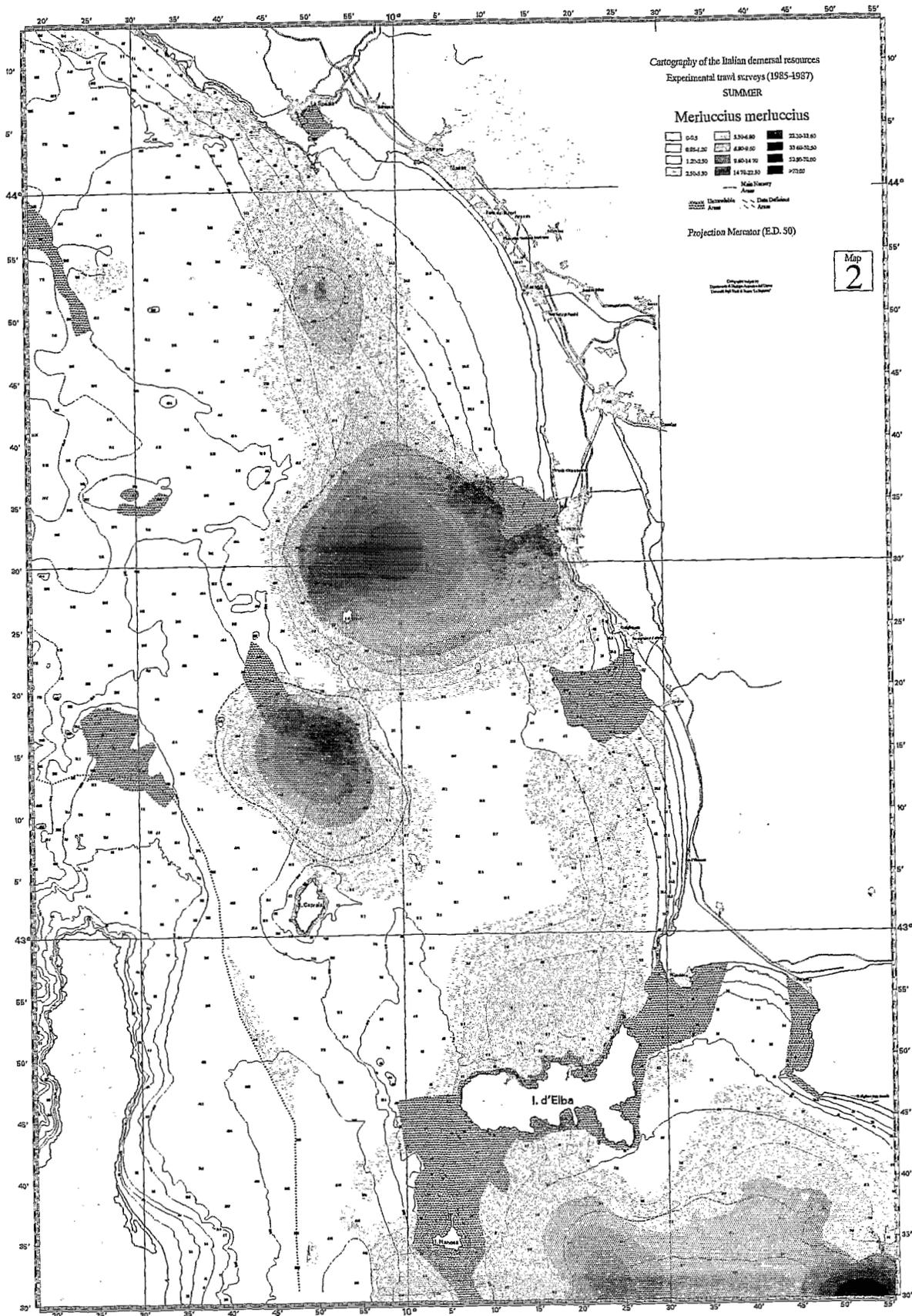


Fig. 2. Sample map of the distribution charts produced. *Merluccius merluccius*, northern Tyrrhenian Sea.

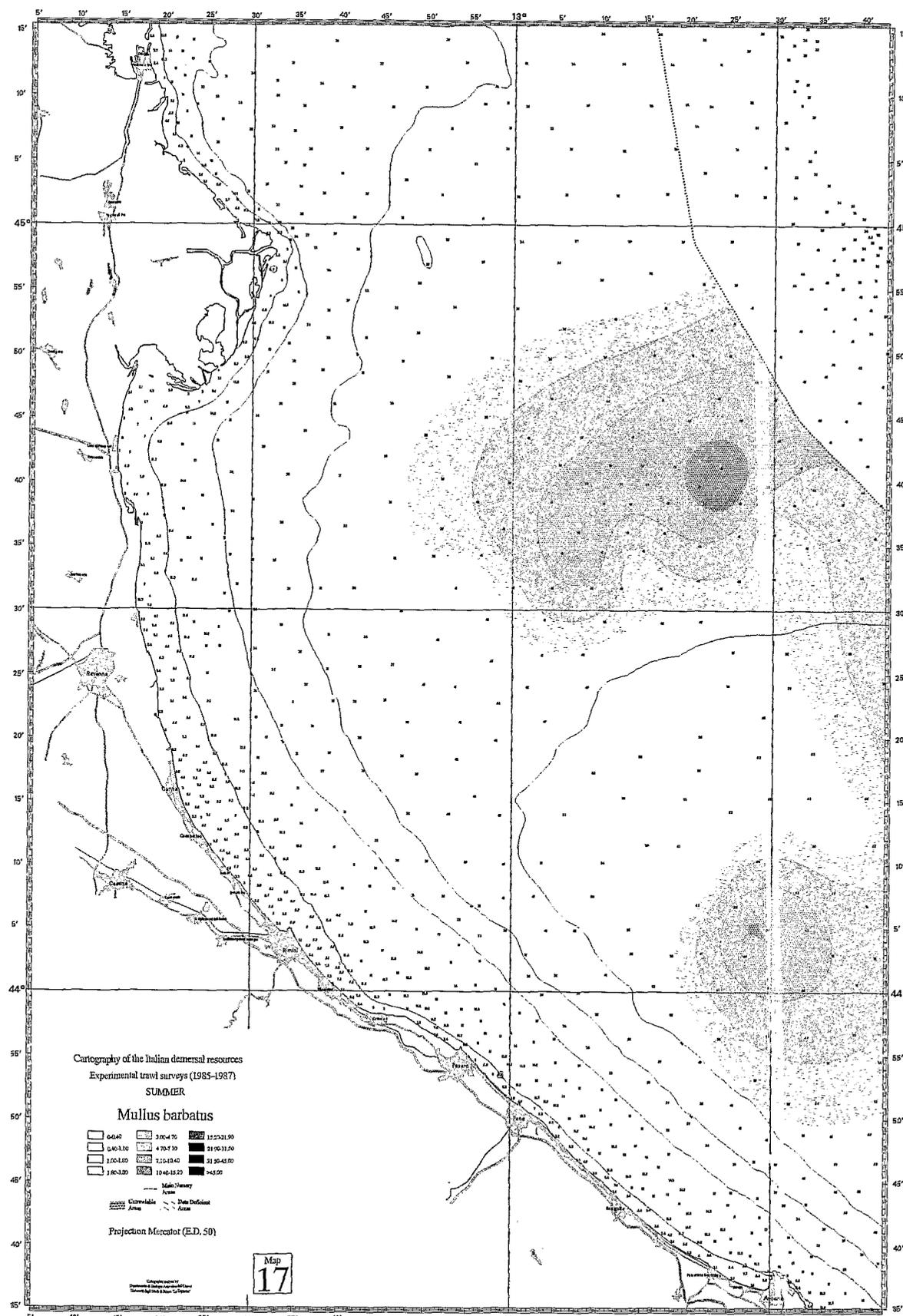


Fig. 3. Sample map of the distribution charts produced. *Mullus barbatus*, northern Adriatic Sea.

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