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Spatial and temporal distributions of some demersal fish populations in the Adriatic Sea described by GIS technique

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In order to enhance the knowledge about spatial *and* temporal *distributions of demersal populations in the Adriatic Sea, which is very important for common fishery policy, the data of relative abundance of some selected demersal species from two extensive trawl-surveys carried out in two distinct periods of time have been analysed; the first one, undertaken in 1948-1949, called HVAR Expedition, and second one, carried out in 1996-1997, under the scope of EU MEDITS program (International Mediterranean trawl surveys).*

Taking into account the information system possibilities for a clear, cartographic description of demersal population space and time distributions, GIS (Geographic Information Technique) has been applied utilising quantitative data of the relative abundance, standardised as catch ration (kg km^{-2}) of the following fish species: hake (Merluccius merluccius), striped mullet (Mullus barbatus) and fish group Chondrichthyes. Applying this technique common, shared and dynamics features of some demersal Adriatic stocks have been clearly described.

Key words: Adriatic Sea, *common* and *shared* stocks, *spatial* and *temporal* distribution,

INTRODUCTION

In the Mediterranean and in adjacent seas, the main demersal fisheries are localised 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, especially because ot the very large dispersion of the landing places, great diversity of the species caught and scarceness of reliable statistics.

As the Adriatic Sea bottom ecosystem of the multi-species resources is highly complex, one of the prime factor for the proper and common management strategy concerning rational utilisation of the groundfish stocks is sound knowledge of the biological and ecological characteristics of the commercial stocks.

According to the framework of EU Mediterranean resources management strategy, MEDITS bottom trawl-surveys program was founded and started in 1994 year. This, still going on activity in the Mediterranean and its adjacent seas encircled several biological and technical objectives among which, enhancement of biological knowledge of commercial stocks

(recruitment, maturity, identification of nursery grounds) and its assessment have been principal goals of the program (BERTRAND, 1996).

Natural characteristics and population dynamics, especially *spatial* and *temporal* distributions of some commercial stocks in semi-locked Adriatic Sea are still insufficiently known.

Though spatial and temporal distributions of Adriatic demersal fish stocks have been already studied (PICCINETTI and JUKIĆ, 1983, 1987; JUKIĆ and ARNERI, 1984; ARNERI and JUKIĆ, 1985; CHARBONNIER and GARCIA, 1985) and recently by GIS technique (ARDIZZONE and CORSI, 1997), the problems concerning rational utilisation and necessary management measures in connection to common and shared demersal stocks that migrate, in and out, of national jurisdictions or in response to their behaviour (spawning, feeding) for many "stock-users" still remain unknown.

EU solemn declarations approved at two diplomatic conferences (Crete, 1994; Venice, 1996) in connection to "Fisheries Management in the Mediterranean" have obliged coastal states, EU member and non-member countries, that benefit from biological wealth from the Mediterranean marine resources, for an effective, sub-regional, scientific and technical co-operation. By following such strategy, a special attention has been payed to possible implementation of the management measures concerning already depleted groundfish stocks on Mediterranean northern and western shelves and slopes.

Management tasks for more rational utilisation of Adriatic bottom resources, since 1990 became more demanding because of the fishing rights endorsed by UN Law of the Sea. Taking into account such fishing rights the East Adriatic coastal states intend to extend fishing areas outside of territorial waters. Utilisation of potential fishing rights in Adriatic trawl fishery, and contemporaneus neglecting of present stocks size and fishing effort, especially *common* and *shared* features of some already depleted commercial stocks, in some instances, will not cover investments.

MATERIALS AND METHODS

In this study, scientists, mostly ichthyologists from Adriatic research Institutes: Split (Croatia), Fano (Italy) and Ljubljana (Slovenia), analysing the available data undertaken throughout the two trawl-surveys in 1948-1949 and 1996-1997, have tried to describe, for the management purposes, very important *spatial* and *temporal* distributions for some selected and economically important demersal stocks. Analyses included fishing areas in national and international waters of central and northern Adriatic Sea. In application of GIS (Geographic Information System) cartographic technique relative indices of selected fish species and fish group collected during the two research activities have been considered and species catch per unit effort (kg h^{-1}) standardised as catch rate per "swept fishing area", i.e. kg km^{-2} (SPARRE and VENEMA, 1992).

GIS (Geographic Information System) technique represents an objective analysis software tool which uses the probability theory in estimating statistics relating spatial variables and their presentations in graphic form. In the study, tasks were done in three steps. First, the structural analysis characterised by different aspects of the spatial distribution. At that stage, one of the models was chosen for interpretation of the data. The second stage involved the model to derive the estimates and third stage, graphical presentation of the results and overlaying of the analysed variables.

Generally, spatial distribution of demersal fish populations in the sea is non-stationary and anisotropic, so that non-linear structural model must be used for their analysis. Using two basic assumptions: homogeneity of spatial correlation at least for the short distances and the possibility of studying all the value ranges together, linear and stationary objective analyses were used. Based on these assumptions, analysis of spatial and temporal distributions of fish and fish assemblages were made respecting relative indices of abundance (kg km^{-2}) for both surveyed periods: 1948-1949 and 1996-1997. Analysis were limited by the nature of the data set (scattered in space), characteristics of objec-

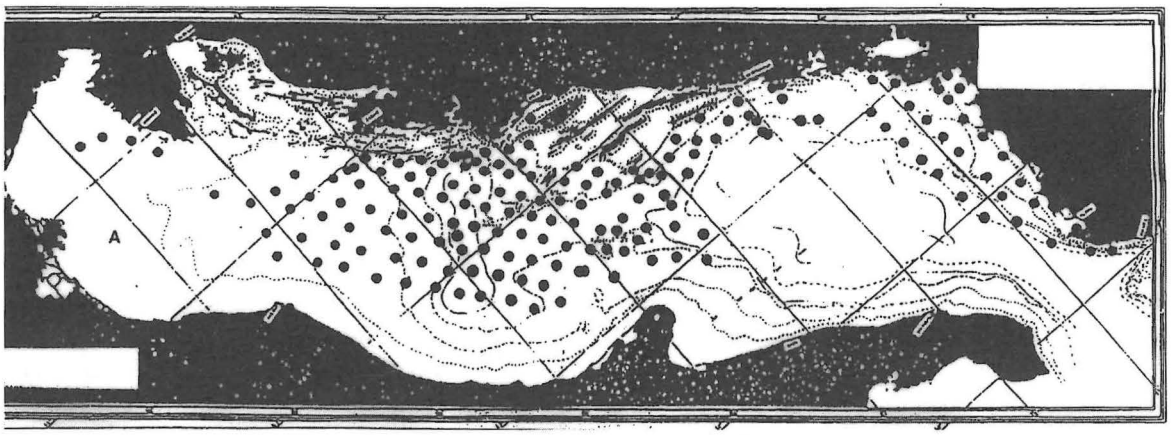

Fig. 1. Geographic position of the selected stations of HVAR exploratory survey carried out during 1948-1949 year in the Adriatic Sea

tive analysis (ordinary kriging, linear variogram model) and grid used (15 Nm x 15 Nm).

During the HVAR exploratory trawl-surveys in 1948-1949, biological data were collected with Italian bottom trawl net, called "tartana" with following characteristics: length of trawl 52 m, foot rope 44 m and stretched cod-end mesh size of 26 mm. Indices of species abundances were collected from over 172 systematic selected stations in northern, central and southern Adriatic (Fig.1). During the HVAR trawl-survey one hour towing time was performed and, except in October, biological data were collected throughout the 1948-1949 year (KARLOVAC, O., 1959).

Under the scope of MEDITS trawl-survey program carried out in 1996 and 1997 in the Adriatic Sea, special French synthetic bottom trawl net, with high vertical opening (GOC 73, IFREMER) was used (FIORENTINI and DREMIER, 1998). Indices of species abundance for: hake (*Merluccius merluccius*), striped mullet (*Mullus barbatus*) and Chondrychthyes fish group were collected over 137, randomly selected stations and stratified according the sea depth (stratum) with geographic surface unit of 200 Nm (15 Nm x 15

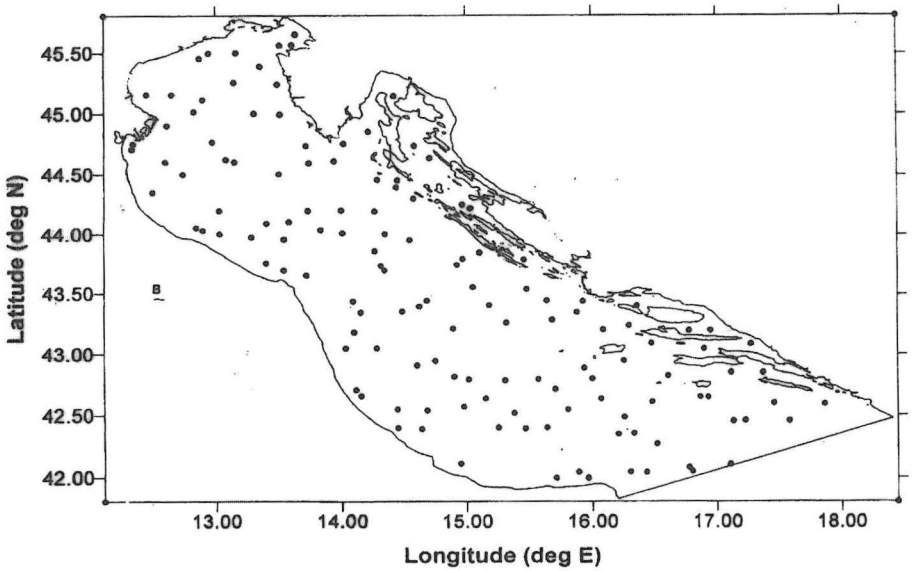

Fig. 2. Geographic position of the selected stations of MEDITS trawl-survey carried out durring 1996-1997 year in the northern and central Adriatic Sea

Nm) for the Adriatic Sea (Fig. 2). Towing time was half an hour and one hour for stations beyond 200 meters.

In comparison to the HVAR trawl-survey program, MEDITS actions were carried out only during the summer time: June 1996 and July 1997.

Taking into account the assumption that catch per unit of effort is a direct function of stock size in the sea, and that changes in catch per unit effort are proportional to the population size (RICKER, 1940; GULLAND, 1969; ALVERSON and PEREYRA, 1969), by application of GIS technique for Adriatic demersal populations of: hake (*Merluccius merluccius* L.), striped mullet (*Mullus barbatus* L.) and fish group Chondrichthyes the following results were obtained.

RESULTS

Analyses made by application of GIS technique in connection to some selected fish species indices of relative abundance, standardised as kg km^{-2}, provided us with better and more clear knowledge of species spatial and temporal distributions of: hake (*Merluccius merluccius*), striped mullet (*Mullus barbatus*) and cartilaginous fish group (Chondrichthyes) in the Adriatic Sea. Achieved results for two surveyed periods, 1948-1949 and 1996-1997, are shown in Figs. 3, 4, 5 and 6.

Results of spatial and temporal distributions of hake, striped mullet and Chondrichthyes fish group described in Figs. 3, 4, 5 and 6, confirm already known characteristics of species geographic distributions in the Adriatic (KARLOVAC,O., 1959), insufficiently understood by fishermen on both Adriatic coasts. The great part of Adriatic demersal stocks are *common* and *shared* and are, depending on their horizontal migrations in and out of national waters, the objects of all Adriatic "stock users".

Results of Figs 3, 4, 5 and 6 indicate as well that aggregations in the form of patches of the selected fish groups in both surveyed periods occur within trawl fishing grounds in the central open Adriatic (international waters) and more pronounced concentrations inside the Croatian national waters.

Higher aggregations of fish school recorded along the Italian coast (Fig. 5b) during the MEDIT'96 surveys belong to "small pelagic" (sardine, anchovy) and cartilaginous fish group drawn in Figs 5c, 6a and 6c for stations west of peninsula Istra (Croatia).

The scope of both trawl-survey and monitoring actions, in 1948-1949 and 1996-1997, indicated the highest concentrations of populations of hake (*Merluccius merluccius*) and striped mullet (*Mullus barbatus*), that were recorded along the eastern Adriatic coast, particularly inside the Croatian national waters. Higher aggregations of some species inside the Croatian national waters, especially in the case of striped mullet population, could be explained either as species preference to the bottom sediment richness with micro-faunal elements (ŠIMUNOVIĆ and JUKIĆ, 1983), or a smaller fishing intensity. Hake population aggregations could be connected with species food and feeding habits, i.e. predator-prey relationship between hake and small pelagic fish populations (sardines, anchovies) that concentrate around Croatian islands and inside of eastern Adriatic channel regions (JUKIĆ, 1975).

Natural characteristics of demersal resources along the eastern Adriatic coast, especially their higher yields were subject of negotiations between Italian and Croatian representatives throught the years.

Analysis of catch per unit effort data for *Chondrichthyes* fish group in 1948-1949 and 1996-1997 and its percentage changes in bottom assemblage structure, especially in connection to *Osteichthyes* fish group, within two investigated periods pointed out that cartilaginous fish group in 1948-1949 was present, on average, with 32,5% and dominated among the other demersal species. Analysis made in 1996 and 1997 year pointed out significant percentage decrease of this fish group. (Fig. 7); 13.3 % in 1996 and 15.9 % in 1997, and it seems that the species percentage decrease, within demersal, ichthyofaunal assemblages should have been foreseen as a consequence of the fishing effort and changes in bottom communities ecosystems (D'ANCONA, 1950; GISLASON, 1994) as well as their biological growing and fecundity patterns.

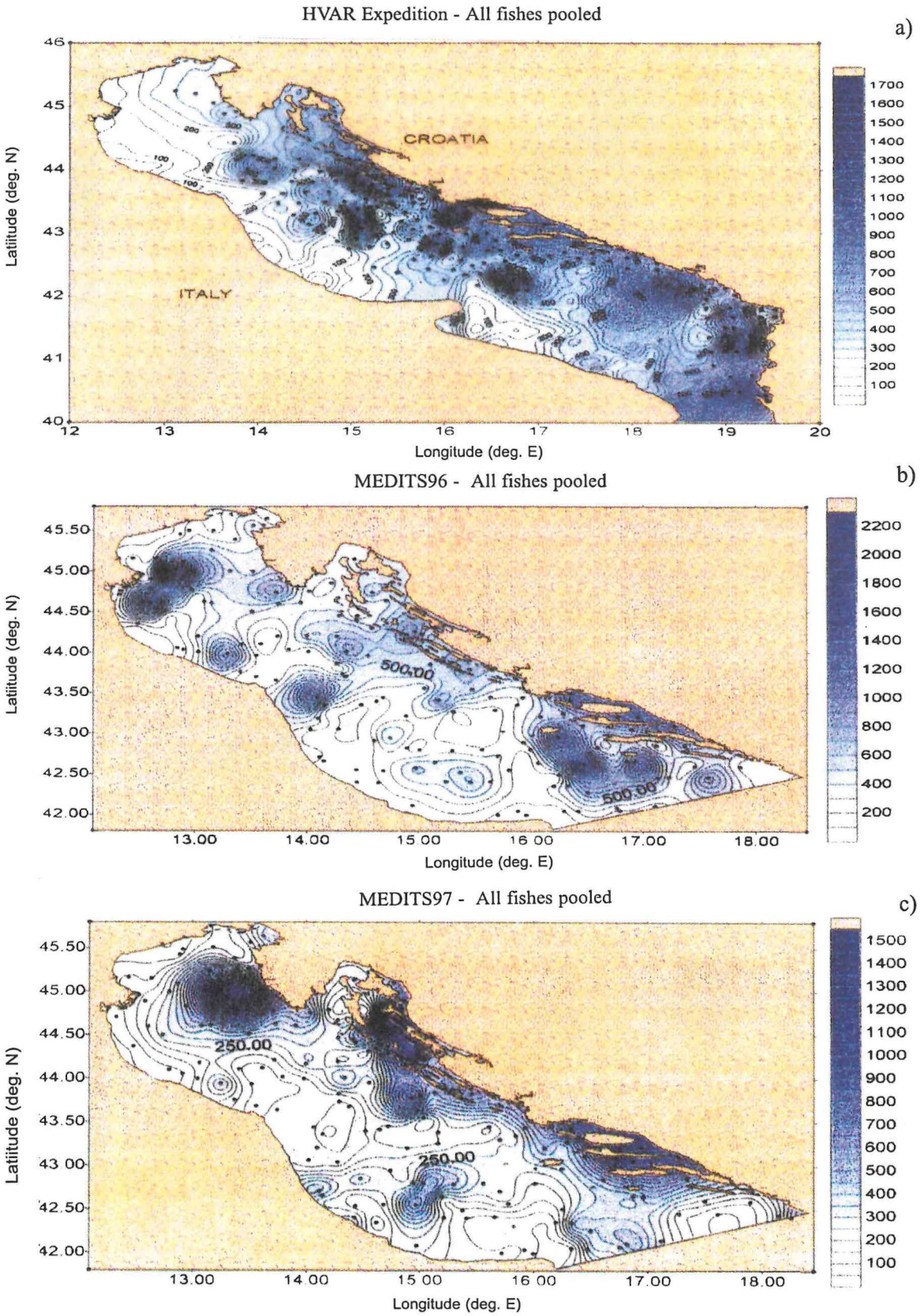

Fig. 3. Spartial and temporal distribution of all fishes pooled

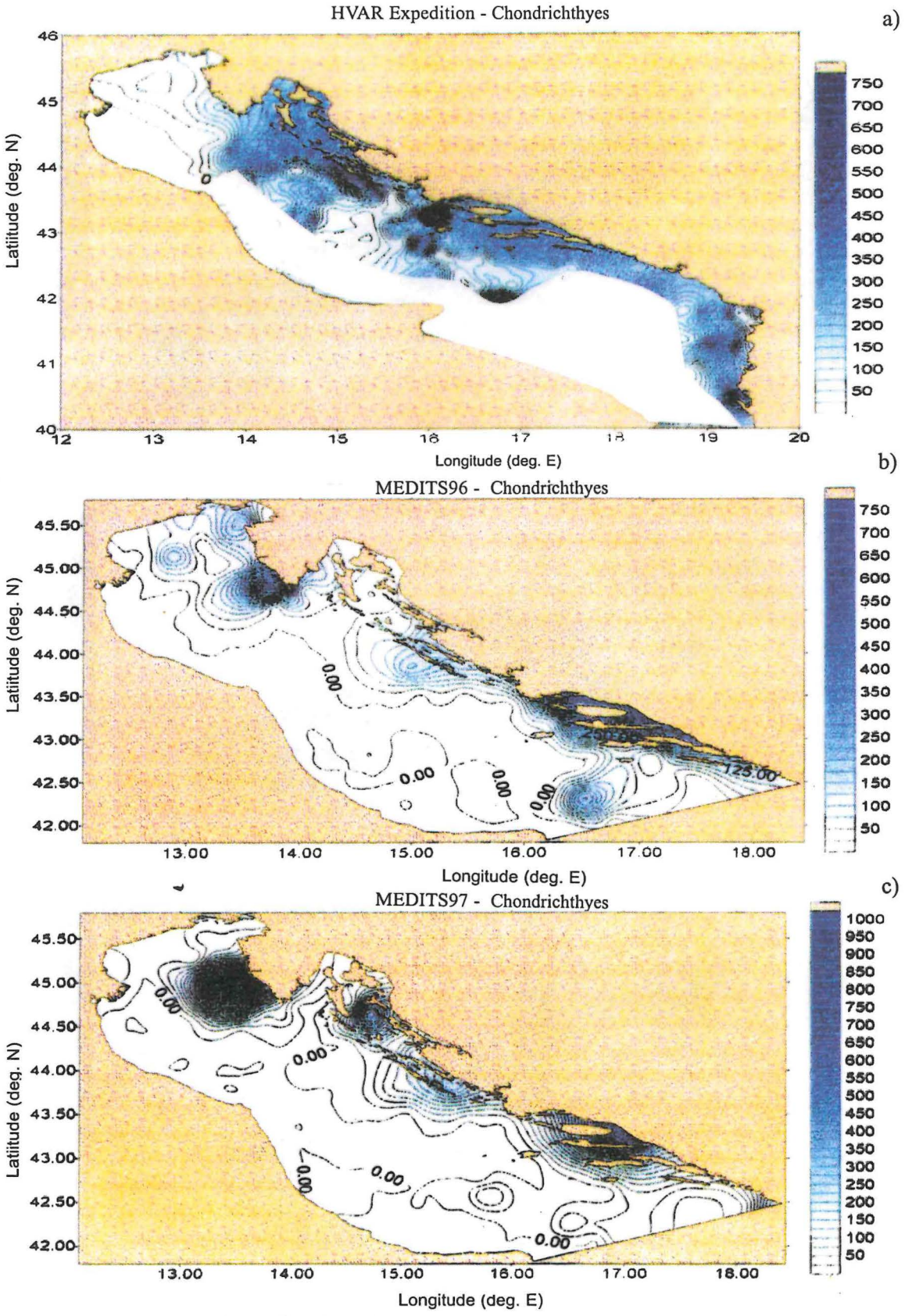

Fig. 4. Spartial and temporal distribution of Chondrichthyes

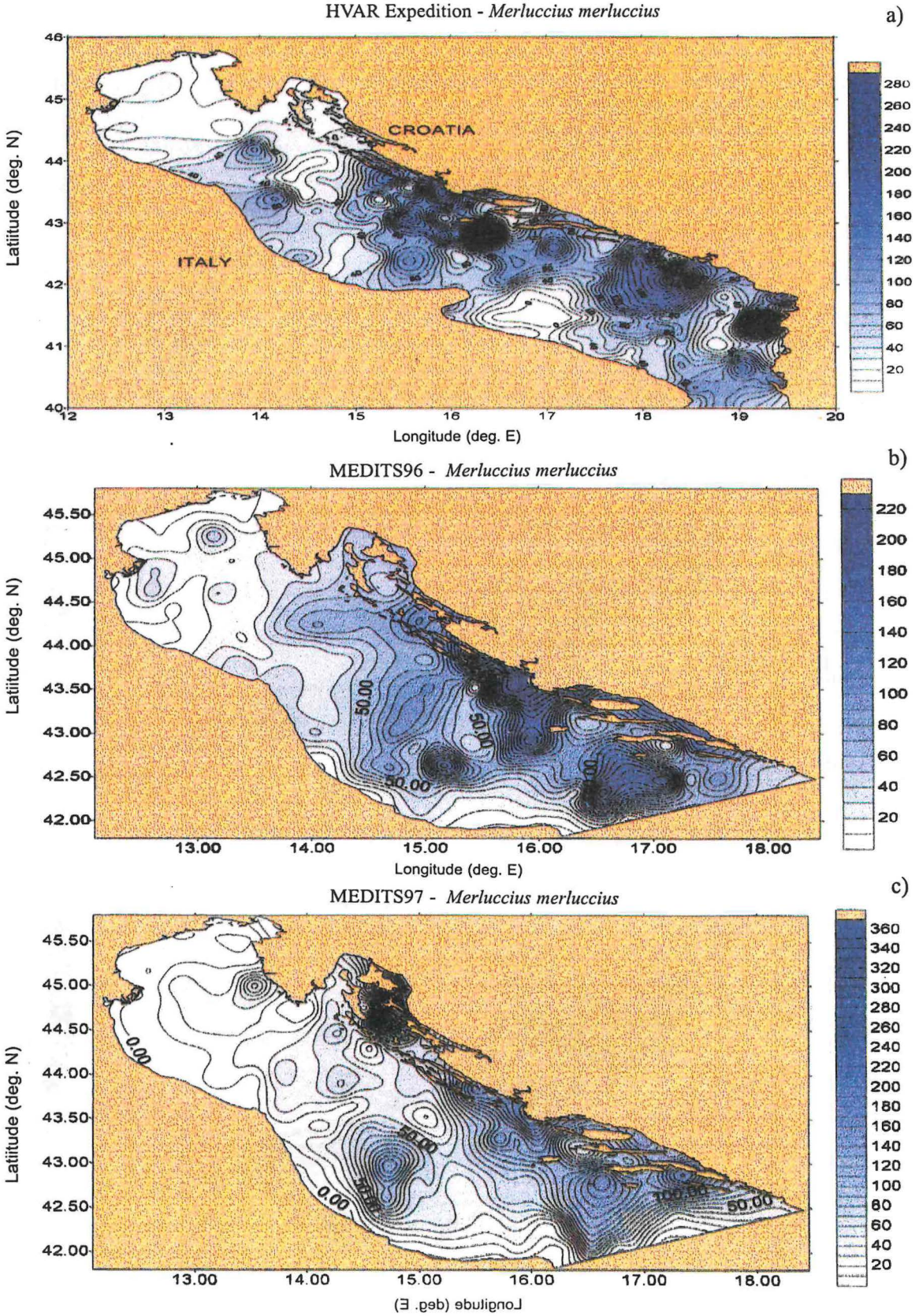

Fig. 5. Spatial and temporal distribution of Merluccius merluccius

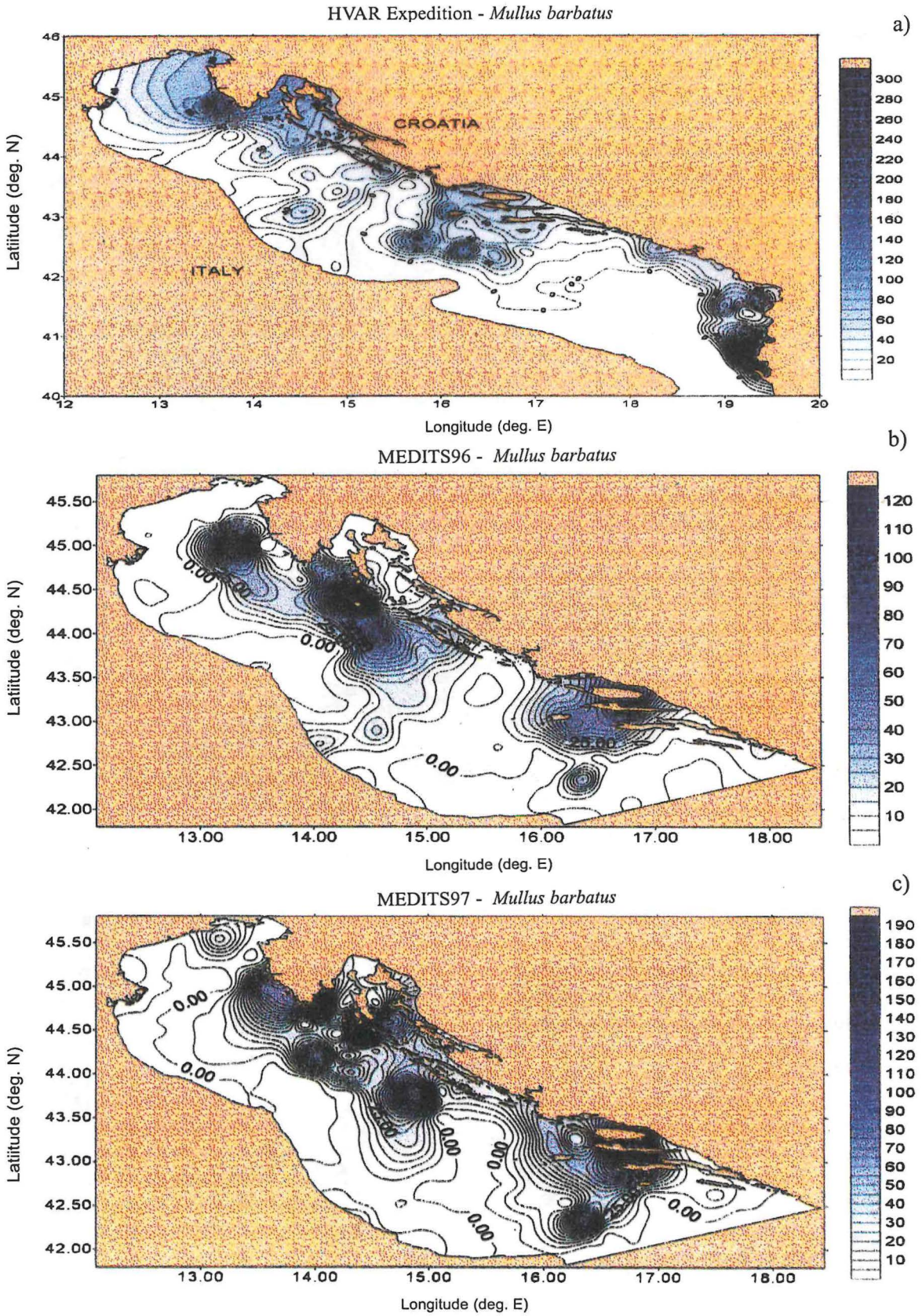

Fig. 6. Spartial and temporal distribution of Mullus barbatus

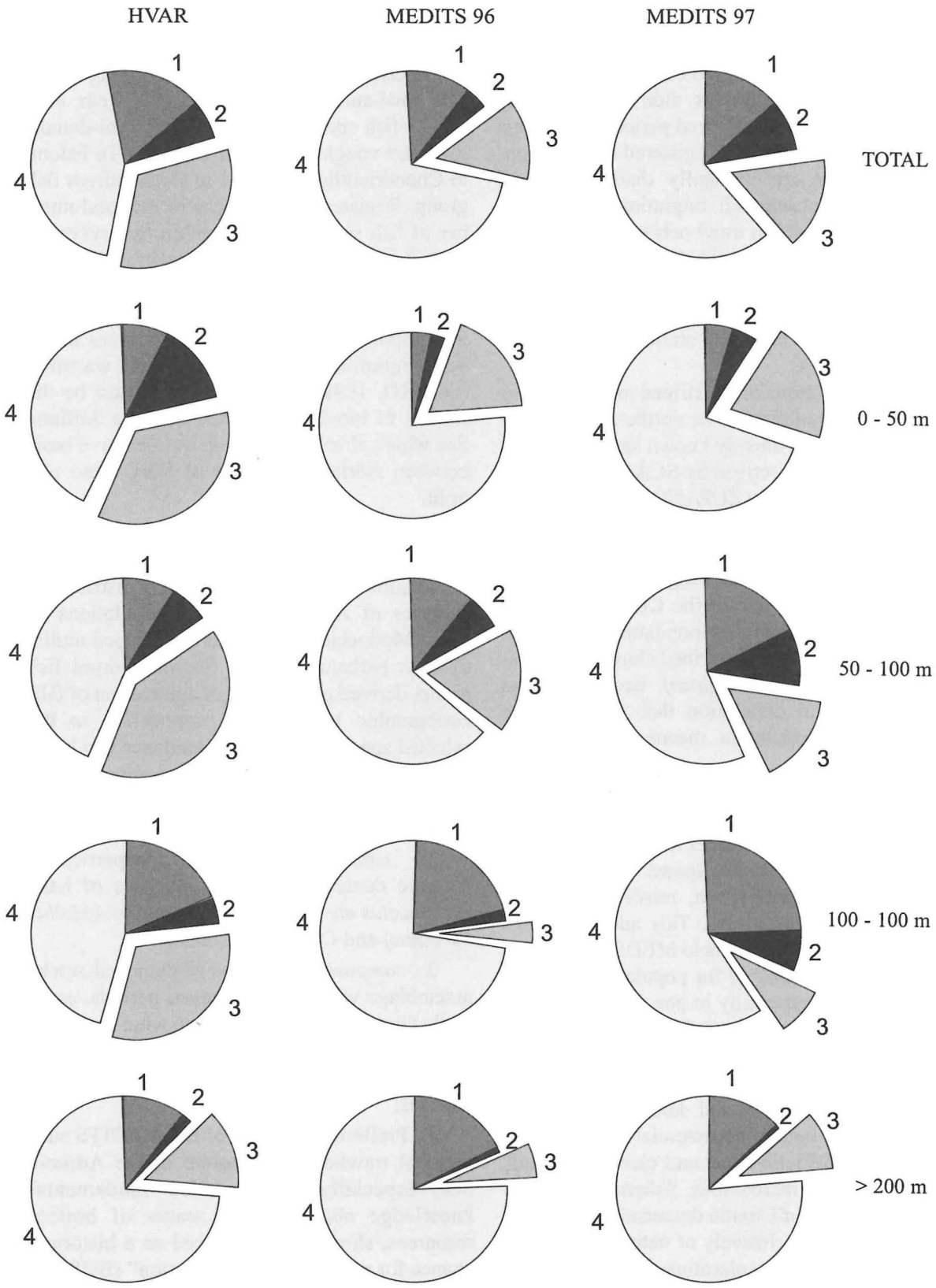

Fig. 7.Structure of Adriatic fish expressed as percentage of weight for all fish together: 1- Merluccius merluccius *2-* Mullus barbatus, *3-Selachii; 4-Other fish species.*

As far as the demersal stocks quantitative structure is concerned, analysis of the indices of species abundance pointed out that striped mullet and hake populations didn't change very much between two surveyed periods. Variations of percentage values are registered only for populations that are vertically distributied and because of that seasonal, migrations and vulnerability to the bottom trawl nets used.

Percentage values of hake (*Merluccius merluccius*) population are smaller at stations inside the Croatian shallow waters (stratum 0-50 m), while they are higher in stratum between 100 and 200 metres.

Concentrations of the striped mullet (*Mullus barbatus*) population in the northern and central Adriatic confirm already known species biology and behaviour, described by SCACCINI (1947), HAIDAR (1970) and ŽUPANOVIĆ (1961), that the species does not migrate deeper than 150 meters. In deeper wathers of the Adriatic Sea, only few individuals are caught.

Statistic analysis of the CPUE values for hake and striped mullet populations in 1948-1949 and 1996-1997 described clumped population distribution (*contagious)*, because it was found for both population that variances are higher than population means (2) (ELLIOT, 1977).

During the MEDITS trawl-surveys biological analysis, especially gonad's maturity examination of the striped mullet females pointed out that mature individuals spawn over the vast areas of the Adriatic Sea, mostly during the summer time (June-July). This additional biological knowledge, thanks to MEDITS program, might be very valuable for population management strategy, especially in possible application of the "closing areas" or "fishing season" policy.

MEDITS biological analyses insured the extension of fundamental knowledge for the major part of bottom commercial species along the eastern Adriatic coast and channel regions, assuring some incredulous fishermen, that in national waters of Croatia demersal fish populations don't die exclusively of natural causes.

During HVAR exploratory trawl-surveys in 1948 and 1949, 142 fish species (demersal and semi-demersal) were caught. From that number 27 fish species belong to Chondrichthyes and 115 to Osteichthyes to fish group. During MEDITS trawl-surveys in 1996 and 1997 year, total of 127 fish species (demersal and semi-demersal) were caught. Out of that number 16 belong to Chondrichthyes and 111 to Osteichthyes fish group. Registered differences in the total number of fish species caught within two surveyed periods, especially as far as Chondrichthyes fish group is concerned, should be considered as a consequence of high fishing pressure or biological responses of the exploited resources to the oceanographic changes, i.e. sea warming (QUERO, 1998). These aspects should be the subject of bio-diversity studies in the Adriatic Sea which already started on co-operative basis between Adriatic institutes of Bari, Fano and Split.

CONCLUSIONS

Results of spatial and temporal distribution analyses of Adriatic demersal populations of hake (Merluccius merluccius L.), striped mullet (Mullus barbatus L.) and Chondrichthyes fish group, derived on the basis of application of GIS cartographic technique in connection to the selected species indices of abundance (kg km^{-2}) within two, in time, distinct trawl-surveys periods:1948-1949 and 1996-1997, show the following:

1. *common* and *shared* properties of Adriatic demersal stocks in the case of hake (*Merluccius merluccius*), striped mullet (*Mullus barbatus*) and Chondrichthyans ;

2. *composition* changes of demersal stocks assemblage within two surveyed periods, especially Chondrichthyes fish group what should be foreseen as a consequence, either of fishing pressure or hydrographic, sea water warming, changes;

3. Preliminary results of EU MEDITS subregional trawl-survey program in the Adriatic Sea, especially the extended fundamental knowledge about present status of bottom resources, should be considered as a historical chance for necessary "reconciliation" (BURKE, 1775) among "stock users".

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Prostorna i vremenska rasprostranjenost nekih pridnenih vrsta riba u Jadranskom moru opisana uporabom GIS kartografske tehnike

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SAŽETAK

U cilju proširenja znanstvene spoznaje o ekologiji i dinamici, a time i oblicima zaštite pridnenih naselja Jadranskog mora, prostorno *zajedničko* i ekonomski *djeljivo* obilježje oslića (*Merluccius merluccius*), trlje blatarice (*Mullus barbatus*) te skupine riba hrskavičnjača (Chondrichthyes) je studirano po prvi put uporabom GIS (Geographic Information System) tehnike.

U tu svrhu, pregledno je objašnjena prostorna raspodjela slijedećih vrsta pridnenih riba: oslića (*Merluccius merluccius*), trlje blatarice (*Mullus barbatus*) te skupine hrskavičnjača. Analizom relativnog indeksa abundancije proučavanih vrsta riba, odnosno ulova na jediničnu lovnu površinu (kg km^{-2}) u području sjevernog i srednjeg Jadrana, nađeno je da navedene gospodarske vrste riba, u biološkom i gospodarskom pogledu, predstavljaju *zajednička* i *djeljiva* biološka dobra Jadranskoga mora, čime je potkrepljena pretpostavka o potrebnoj uspostavi dogovorne politike između korisnika obnovljivih bogatstava Jadranskoga mora.