ANNEX II

Annex II Presentation summaries submitted by workshop participants

CONFIGURATIONS OF ENVIRONMENTAL PROCESSES REGULATING POTENTIALLY SUITABLE PELAGIC FISH REPRODUCTIVE HABITATS IN THE MEDITERRANEAN SEA

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A framework of comparative climatology of reproductive habitats of pelagic fishes has been extended in this study to the Mediterranean Sea. Maritime weather reports have been summarised to yield seasonal distributions of wind speed cubed, wind stress, Ekman transport, upwelling/downwelling and sea surface temperature. Seasonal distributions *maps of* the parameters mentioned above were produced. These distributions were considered with other known aspects of oceanography and elements of anchovy life history in the region. Configurations of environmental processes affecting transport, water column stability and trophic enrichment ("triad concept") will be outlined. Potential favourable reproductive habitat areas in the Mediterranean will be discussed. This study uses pattern recognition as a conceptual framework for the definition of environmental processes potentially impacting pelagic fish habitats and distribution geographies in the Mediterranean Sea.

SMALL PELAGIC FISHERIES AND ENVIRONMENT IN THE ADRIATIC SEA - IRPEM DATABASE

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Anchovies *(Engraulis encrasicolus, L.)* and sardines *(Sardina pilchardus, Walb.)* are very important fishery resources in the Adriatic. The Adriatic Sea, which is about one twentieth of the surface of Mediterranean, yields about 20% of the Mediterranean (Cingolani et al., 1996a,b) and more than 70% of Italian anchovy catches (ISTAT, 1975-1994). A similar situation applies to sardines. In 1975, IRPEM started a regular collection of data on fishing effort and fleet characteristics, catch data by species and biometric data such as catch length-frequency distributions, length-weight and age-length relationships. Biometric data and those regarding the fishing effort have been collected in the most important Adriatic fishing harbours for small pelagic fish, whereas data regarding catches also come from minor ports as well as from the eastern shore of the Adriatic (former Yugoslavia, now Croatia and Slovenia). This sampling scheme has allowed a wide coverage in both temporal (more than 25 years) and geographical terms of the northern and central Adriatic, where most of the anchovy and sardine fishing takes place. This database has allowed to estimate the abundance at sea of small pelagic fish populations. Estimates of anchovy stock biomass at sea in the time interval 1975-1996 were obtained using two population dynamics methods based on different data inputs: Virtual Population Analysis (VPA) and DeLury model with recruitment index (Santojanni et al., submitted). Sardine stock biomass values were also estimated for the time interval 1975-1996 (Santojanni et al., in press). These estimates were obtained using three methods based on different data inputs: Length Cohort Analysis (LCA), Virtual Population Analysis (VPA) and an *"ad-hoc"* modified version of the DeLury model with recruitment index.

From this database a group of time series on these two stocks are available: total catches 1975-2000, biomass 1975-1996 (ongoing), two series of recruiment indices: one as a VPA output (numbers in the youngest year class) and a second one as the proportion of small individuals in the catches. As far as anchovies are concerned, the relationship between the spawning stock biomass (in year n) and recruits (in year n+l) stress the fact that high levels of spawning stock biomass can correspond to very different levels of recruits (the same can be said for sardines). This rather loose stock-recruitment relationship is generally considered as evidence of the importance of environmental factors in determining recruitment strength and mortality in the early life history stages of small pelagic fish.

In the last year a project on interannual environmental variability has been funded by CNR (Italian National Research Council): one of the task is to investigate small pelagic fluctuations in the Adriatic. This will be done trying to use fishery data and the meteorological and oceanographic data base collected by or available at IRPEM including:

Meteo station in Ancona measuring air temperature, wind components, air pressure and net radiation from 1996 up to date;
6 hours ECMWF (European Centre for Medium term Weather Forecast) reanalyses since 1979 for mean sea level air pressure, 2 m air temperature, 2 m dew point temperature, wind components,

cloud cover (since 1994).
Monthly Po river runoff since 1918, daily since 1993.
Several hundreds of oceanographic stations (with temperature, salinity, density, and often fluorescence and turbidity) collected from 1980 up to date in the Middle and northern Adriatic Sea, including some biochemical data (above all dissolved oxygen and nutrient salts).
Ongoing oceanographic monthly monitoring of two transects from the Italian coast to Croatian and seasonal monitoring of the Meso Adriatic Depressions (Pomp pits).
ATOS (Adriatic Temperature Oxygen Salinity, Artegiani et al., 1997) data base assembled at IRPEM and constituted by about 4400 historical (published data) oceanographic stations collected from 1911 to 1980 on the whole Adriatic Sea.
NADS (Northern Adriatic Data Set), including about 3400 oceanographic stations collected in the northernmost part of the Adriatic by the Istituto di Biologia del Mare (CNR-IBM**,** Venezia) from 1978 up to date, monthly from last years.
Currentmeters time series (usually 1-2 years) at some points of the western Adriatic Sea.

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UPDATING OUR IDEAS ON THE NATURE OF THE INTERACTION BETWEEN FISHERY RESOURCES AND THEIR ENVIRONMENT

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Evidence is accumulating that many types of fish populations may change their locations of operation within their ocean habitats, not only in annually-repeated seasonal cycles, but also in an evolving progression over much longer multi-annual time scales. This has extremely important implications for the way that we may view marine resource stock assessment and population dynamics. It might also open opportunities for new ways for conceiving innovative adaptive management actions designed to properly balance fishing and environmental pressures so as to maintain the resource populations within, or return them to, their most productive geographical configurations (it might also conceivably be possible even to take deliberate actions to induce movements of the primary zones of operation of particular fish stocks in order to benefit one sub-region at the expense of another, e.g., by shifting the primary reproductive zone from one subregional "ocean triad" configuration to a different one, etc.).

In this introductory presentation, some newly formulated ideas regarding the relation between spatial dynamics and temporal variability in fish population abundance will be briefly outlined. These will include a brief simplified "cartoon" of a sardine-tuna interaction designed to illustrate the operation of a proposed mechanism underlying a hypothetical "school-mix feedback" process. A diagrammatic way to view the process will also be introduced in order to help illustrate how fish populations might act in an adaptive manner to defeat growth of intolerable levels of predation pressure or how they might withdraw themselves from locations of major fisheries, and how conservative fishery resource management might actually serve to keep a population trapped at a suppressed level of productivity, etc. An illustrative example will be shown which deals with the Benguela marine ecosystem off south-western Africa. If time allows, a design will be presented for using comparative empirical retrospective analysis for identifying characteristic adaptive time scales.

The conclusion drawn from of all this will be that many of the same things we have always worried about (stock definition, identification of favorable reproductive habitats, annual estimates of relative reproductive success, information sharing among adjacent countries and regions, etc.) will continue to be vitally important - but even more so. Moreover, there may be promising new ways available to apply this information to the purpose of ensuring productive fisheries operating within a scientifically based framework for sustainable fisheries development.

THE SPATIAL ANALISYS OF MARINE RESOURCES ABUNDANCE INDICATORS CALCULATED USING FISHERY SURVEY DATA

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The presented application is a tool for the scientists working on the spatial analysis of marine resources abundance indicators calculated using fishery survey data.
The surveys data are stored in a relational data base. The application assists the scientist in building selections of sampling stations and calculate abundance index on each station of the selection.
The meta-data related to the selection process and calculation of variables are managed (storage, modification of the selection criteria or variables). The result of a selection is automatically exported from the data base management system to a GIS software where the scientist may proceed to the spatial analysis.
This application has been developed and tested using demersal trawl surveys but should easily cope with pelagic surveys data.

OVERVIEW OF THE MEDITERRANEAN GLOBAL OCEAN OBSERVING SYSTEM (MEDGOOS)

FP5 project: "Mediterranean network to assess and upgrade monitoring and forcasting activity in the region" (MAMA)

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MedGOOS was founded under the auspices of UNESCO / IOC in November 1997 in Malta and its secretariat is hosted by the Malta Operational Centre of the International Ocean Institute. It is a direct response to the challenge to move beyond the success achieved in the political agenda to progress in technical collaboration and to improve the understanding and management of the marine environment in the Mediterranean for the sustainable exploitation of its resources, for monitoring the health of ecosystems, for improving safety of life and property at sea and along the coast. Moreover, MedGOOS will provide a string of operational oceanographic products and services, addressing the requirements of governments and to the benefit of a vast spectrum of customers and industries. The system is designed to operate by means of regional networks for data capture and exchange, to provide descriptions of the state of the sea and its contents in an operational mode with assessments and ocean forecasts at basin and local scales. MAMA**,** which will be operational from October 2001, provides a framework for the concerted basinwide effort to establish a strong and common research infrastructure necessary for the setting up of MedGOOS.

WPO MAMA-CO - Project Integration and Co-ordination

This Work Package aims to create a strong co-ordinated network between partners and with

the user community by integrating the scientific and technical elements - of the program, by harmonising activities of the participants and by ensuring that human and technological resources are put to best use. The strategy of the Global Ocean Observing Systems will be kept as the focus of the project which can also be linked with related European and international

WP1 MAMA-NOW-

An identification and stock taking exercise will be undertaken in order to assess the present state of coastal waters and to implement a viable operational ocean forecasting system. This will be done both in conjunction with international organisations operating in the Mediterranean as well as with authorities on a national level in each individual country.

WP2 MAMA-OBS - OBSERVING SYSTEM

This Work Package will involve a scientific assessment of existing ocean observing systems in the Mediterranean at regional, coastal and national scales. The existing hardware and equipment used for coastal ocean observing platforms and the software used for data pre-processing procedures will be evaluated and compared. The main aim is to have common standards and parameters as well as common protocols to achieve the defined `minimum performance levels'. A networking of satellite data in NRT is proposed and various satellite data centres will be linked to the MAMA WWW. A database will be set up and will consist of existing data on the benthic faunal condition, natural abiotic factors and anthropogenic elements in sediments.

WP 3 MAMA-CAP/BUILD, CAPACITY BUILDING

Capacity building is one of the main aims of MAMA and the sharing of technical and scientific expertise between Mediterranean countries is necessary to allow for full participation in the GOOS. A visitor scientist scheme is being proposed whereby over twenty scientists/technicians will benefit from experience gained in deploying, running and maintaining an operational coastal observing system; in transmission and management of data; numerical modelling and data assimilation.

WP4 MAMA-MODEL

An initial ocean modelling system for the Mediterranean shelf and coast areas will be designed by integrating the experience in modelling carried out in RTD EU Projects such as the MFSPP and by carrying out an assessment of the state-of-the-art of numerical modelling and data assimilation .
Historical information will serve as the basis for the compilation of high resolution regional climatologies and for short range ocean forecasts, whilst optimising techniques to downscale the predictability to coastal and regional subsystems.

WPS MAMA-NET

A regional marine information network in the Mediterranean is imperative for establishing good basis for interagency exchange between data-providers and end-users. This web-based interface will increase accessibility of products and operational data as well as serve as a springboard for the creation of a Mediterranean "virtual ocean centre". A marine data and information management (MIM) workshop will provide guidelines for such an information system.

WP6 MAMA-WWW

The MAMA WWW will act as a reference point in the Mediterranean by having links to national and institutional web sites and operational ocean forecasting programmes. The aim of MAMA WWW is to raise public awareness and to highlight the benefits of operational forecasting to potential users whilst encouraging regional interaction. The dissemination of results on the WWW will also serve to enhance information exchange.
A web-based regional directory, entitled MeDir, will act as a searchable database of marine agencies, institutions and professionals and their activities on operational forecasting in the Mediterranean.

WP7 MAMA-AWARE

awareness campaign will continue throughout the duration of the project and it will promote greater awareness on MAMA and the benefits of ocean forecasting in the Mediterranean in order to secure greater support and the commitments from various governments. It will address a full hierarchy of stakeholders, such as governmental agencies and authorities, policy-makers, marine scientific community, marine industries, services sector, and the public at large.

WP8 MAMA - DISS & PROD, DISSEMINATION & PRODUCTS

Open and constructive links will be established with the end-user community in order to identify their needs and priorities. This will be achieved mainly through the development of a website which will provide guidance and information on ICZM and on protection from coastal erosion. This will form part of the Coastal Erosion Protection and ICZM Guidance Demonstrator (CEROSPIG). The tasks involved will address the need to improve the ability to make use of data for the management of marine resources at short term by developing user-friendly interfaces for viewing ecosystem forecast results and 3D data as well as by embarking upon a dedicated pilot exercise for the coastal zone whereby the merging of in situ and satellite data will provide information on the current trends of the coastal marine environment

EVOLUTIONARY INDIVIDUAL-BASED MODEL FOR THE RECRUITMENT OF THE ANCHOVY IN THE SOUTHERN BENGUELA: TOWARDS A METHODOLOGY FOR UNDERSTANDING SPAWNING PATTERNS

(This presentation is based on a paper submitted to CJAS, by C. Mnllon, P. Cury and P. Penven)

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Evolutionary simulations are developed to explore environmental constraints that select observed spatial and temporal spawning patterns for the anchovy in the southern Benguela. They couple a realistic 3-D hydrodynamic model with an individual-based model in which an evolutionary-based reproductive strategy for adult fish and a passive transport for early-life stages are implemented. The evolutionary success of spawning is quantified when patterns at the population level emerge after many generations from constraints at the individual level through a selective process. Simulated patterns match observed spawning patterns when two selective environmental constraints are associated: a threshold temperature of 14°C, above which the development of early-life stages is insured, and the avoidance of offshore currents that constitutes a loss of spawning products. Other spawning patterns are observed under different selective constraints, indicating the possible existence of several coexisting self-sustaining populations with different recruitment patterns. A differential exploitation of these populations will have a strong incidence on patterns of variability for recruitment. A general methodology is proposed for identifying sets of environmental factors important for self-sustaining populations and fish recruitment. The French south-African Idyle project, within which this modelling experiment was performed, is then presented in order to document several different activities that are currently developed on "Ecosystem Modelling" in the Benguela.

Keywords: Recruitment, reproductive strategy, pelagic fish, anchovy, upwelling, southern Benguela, hydrodynamical 3D model, IBM, evolutionary simulations, viability, self-sustaining populations.

USING NON-LINEAR STATISTICAL METHODS IN ANALYSING FISHERY AND ENVIRONMENTAL TIME-SERIES IN THE BLACK SEA

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The objective of this paper is to present applications of statistical methodologies of studying fish-environment linkages with special reference to long-term changes in the Black Sea.
Locally-weighted regression or *033loess* (Cleveland, 1993) and Seasonal-Trend decomposition based on *loess4* (STL Cleveland *et al.,* 1990) are used to analyse time-series. Principal component analysis (PCA, Lebart *et al.,* 1995) is applied in order to compare long-term patterns in multiple series. Fish recruitment is modelled in relation to the adult stock and environmental factors using Generalized Additive Models (GAM, Hastie and Tibshirani, 1990).
rinOVarious hydroclimatic (SST, SLP, wind, run-off...), biological (phyto- and zooplankton, jelly-fishes...) and fish stocks (recruitment and parental stock abundance of anchovy, sprat, horse mackerel and whiting) long-term data are studied in order to describe and compare the main trends and fish-environment relationships in the Black Sea ecosystem. Longterm patterns are analysed on different temporal scales: trend, interdecadal, decadal and interannual variation. The results show evidence of coherent patterns between physical, biological and anthropogenic series. Temperature, atmospheric pressure, wind and run-off series are significantly correlated with most of the biological and fish stocks indices.
Significant correlations appear between fish recruitment, stock biomass and physical environment. Patterns of the recruitment response to wind forcing and sea level atmospheric pressure are similar in four fish species. Recruitment in the off-shore reproducing sprat and horse mackerel is less dependent on the parental stock biomass and is related to the thermo-haline circulation, while in the coastal species - anchovy and whiting - is related to the river run-off.

The established correlations allow formulating hypotheses on the causal links between the abiotic environment, productive processes and population dynamics. The physical environment is recognised being the main factor driving the biological productivity and essentially influencing all processes in the sea. Other factors responsible for a great part of the observed variability in marine data series are biological interactions and anthropogenic impact. The rise in overall productivity after 1970 can be explained by several factors acting simultaneously: hypothetical favorable climatic regime, increased eutrophieation, and trophic cascade effect du to the predator's extinction propagating down the pelagic food-web.The obtained results can enable the integration of reliable environmental indices in the procedures of fisheries and ecosystem assessment and management. The statistical methods used are found to be suitable tools for fisheries and environmental data analysis, providing flexible and powerful way to explore and model non-linear relationships.

Keywords: Fish-Enviroment, Climate regimes. Decadal changes, Recruitment, Ecosytem structure, Loess, Gam, Black Sea.

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THE STATUS AND DIRECTION OF STOCK ASSESSMENT FOR SMALL PELAGICS IN THE MEDITERRANEAN

Co-ordinator of the Subcommittee on Stock Assessment

-Jordi Lleonart-

- Overview of the small pelagics assessment in the Mediterranean: SAC, SCSA and WG on small pelagics.

- Standard forms
- Priority species: *Engraulis encrasicolus, Sardina pilchardus, Sardinella aurita, Sprattus sprattus, Trachurus trachurus.*

- *Engraulis encrasicolus*

- Collapses
- Can the anchovy be assessed by population dynamics? Direct and indirect assessments.
- The risk of recruitment overfishing. The minimum legal size and length at first maturity

- *Sardina pilchardus*
- Selected general conclusions of the SCSA

- Due to the potential danger of recruitment over-exploitation in anchovy, it is recommended to set the minimum legal sine to length of first maturity.
- Encourgage multi-species assessment and ecological approaches
- Multi-species assessments and ecological approaches in fisheries studies are encouraged.
- It was stated that only two small pelagics shared stocks have been assessed and was strongly recommended to present assessment for additional shared stocks.
- It was pointed out the poor representation of scientists of eastern and southern Mediterranean and Black Sea

OTOLITH MICROSTRUCTURE STUDIES APPLIED TO FIELD CAPTURED LARVAL ANCHOVY AND SARDINE IN THE MEDITERRANEAN

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Anchovy and sardine larval otoliths show microstructures resulting from the deposition of increments in the outer edges of the otolith, which in the case of these species are of daily nature. This natural feature allows to have the growth record of an individual and to define the growth pattern of a sampled population of larvae and thereby, allowing a quantitative evaluation of the growth rates. The otolith microstructure methodology provides an important tool for assessing the survival potential of a population by offering the possibility of identifying sub-optimally growing larvae, or individuals at risk in natural conditions. Since growth of fish larvae in the field is mainly affected by food uptake and by temperature (Heath 1992), the otolith microstructure analysis is a practical tool for assessing the influence of environmental conditions on the growth parameters of a larval population.

In the course of the past years, different EU funded multi-disciplinary projects on the Mediterranean anchovy and Mediterranean sardine have implemented the larval otolith microstructure analysis. The present document presents different applications of otolith microstructure analysis to field-captured Mediterranean anchovy and sardine.

Aiming at the larval ecology aspects of the NW Mediterranean anchovy *(Engraulis encrasicolus),* larvae were sampled for estimating daily growth and condition (RNA/DNA ratios) off the Gulf of Lions and the Catalonian coasts during the anchovy peak spawning season (García *et al.,* 1994). The anchovy larval population sampled was stratified into two contrasting sites from the environmental conditions viewpoint. The Gulf of Lions is characterised by its high productivity due to shelf-slope front of the Ligurian-Provenzal current, the haline fronts produced by the Rhone river outflow (Castellon *et at.,* 1985) and wind-induced coastal upwelling (Cruzado, 1990). The anchovy spawning off the Catalonian coasts shows in comparison generally lower production rates. The temperature conditions of both regions also show differences, the Gulf of Lions being cooler (~2°C less). The results of this study (Garcia *et* al., 1999) showed that larvae from Gulf of Lions had significantly higher daily growth rates than anchovy larvae from Catalan Sea, and, consequently, sagittal size measured in terms otolith area and radius from Catalan Sea were smaller than those from Gulf of Lions. Moreover, the condition estimates by the quantification of nucleic acids support the daily growth analysis because the larvae captured in the Gulf of Lions had significantly higher RNA (µg/larvae) vs DNA (µg/larvae) relationship, thus a better condition.

During 1997, the Sicilian Channel anchovy larval population was sampled off Cape Passero for a daily growth and condition analysis (Mazzola *et al.,* 1999). The environmental conditions of the Sicilian coasts is characterised by its oligotrophic nature and the warm surface temperatures (~24°C) in the sampled area. These contrasting differences in respect to the previous study are reflected in the lower daily growth rates of the Sicilian Channel anchovy. The results of this study, on the other hand, supported further evidences of transport from the north-western anchovy spawning grounds

towards the Cape Passero region located in the southernmost end of the island.

The greater average size of larvae and their estimated ages support the advection by the AIS (Atlantic Ionian Stream). The mean anchovy larval size in the Cape Passero region (11.5 mm) provided a sufficient time span (14 days) for advection duration from the northern spawning grounds to the southern feeding grounds. 'thus, daily growth studies may also provide information for following transport trajectories from early larval stages to post-larval stages.

In species such as the Mediterranean sardine that have prolonged spawning seasons, which may extend from autumn (October) to spring (May). with spawning peaks located in winter, the otolith microstructure analysis may also reveal differences in the daily growth parameters. In the context of another EU cofinanced project, PARS**,** the Alboran Sea sardine larvae were sampled in the same sites during winter and spring for daily growth and condition analysis (Moksness et al., 2000). The sardine larval cohorts sampled during the winter and spring of 1998 showed sionificant differences. The spring sardine larval populations showed higher daily growth rates than the winter-spawned population. This difference may be caused by the higher temperature regime and feeding availability caused by the typical spring planktonic blooms.

Another important focus of attention was paid in the precision and accuracy of age determination (PARS) by otolith microstructure. Examples of precision gain in the Alborán Sea sardine will be discussed in the presentation.

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HYDROGRAPHIC CIRCULATION VARIABILITY AND ITS EFFECTS ON THE ANCHOVY EGG AND LARVAL DISTRIBUTION PATTERN OFF THE SICILIAN COAST

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A Study of the Sicilian Channel anchovy supported by the European Union (Mazzola et al. 1999) identified during surveys curried out in 1997 and 1998, a relationship between the general circulation pattern of the Atlantic Ionian Stream (AIS) off the Sicilian Channel and the anchovy reproductive strategy (Giarcía Lafuente, et al.. in press). The main anchovy spawning grounds and its fishing grounds are located in the northwestern region of the southern Sicilian coast. During the 1998 survey this region was identified as a low current area of hydrographic stability due to the impingement of the AIS towards the coast and its bifurcation into two branches. The main branch, which follows a southeastern direction along the coast towards Cape Passero (located in the SE end of the island), transports anchovy eggs and larvae downstream. The geostrophic density front. which is originated by the shoreward sloping of isopycnals in order to maintain the geostrophic flow at the left side of the AIS trajectory facing Downstream, facilitates mixing of deeper waters with surface layers and enhances the primary production. thus assuring food availability for larvae during their advection.

As a result of this advection, the main anchovy larval concentrations are found off the SE end of the Sicilian coast, in the area off Cape Passero. The greater average sizes of larvae and their estimated age confirm the evidence of the advection by the AIS. On the other hand, the hydrography off Cape I'assero is characterised by a welldefined cyclonic vortex that favours upwelling of deep water at its centre and provides a suitable environment for sustained enhanced rates of primary production. At the same time, larval population can maintain the relative position inside this vortex without much difficulty. Therefore, the Cape Passero region can be defined as a retention area favourable to provide the necessary feeding conditions for larval growth. The observed distribution of the young-of-the-year anchovy, mainly located in this region, supports further evidence of this nursery ground.

In the light of additional information provided by the anchovy egg and larval surveys carried out during the years 1999 and 2000, the variability observed in the anchovy egg and larval distribution pattern is analysed comparatively with the variability of the hydrographic circulation. Some factors can modify the AIS flow in the channel, namely the intensity of upwelling over the Adventure Bank (a large continental shelf located in front of Mazara del Vallo, at the NW part of the southern Sicily coast). the climatic regime, or the dynamical properties of the Modified Atlantic Water that forms the Algerian current when it detaches from the African coast at the western entrance of the Sicilian Channel. The actual path of the AIS has important influence

on the anchovy reproductive strategy. For instance, during the surveys of years 1999 and 2000, Sea Surface Temperature images suggested that the AIS flowed far from the Sicilian coast in the western half of the channel arid approached the shore further south than in the previous year (1998). This circulation pattern enhanced the southern anchovy spawning grounds and lessened the relative importance of the northern ones. Not withstanding, the AIS atdvection towards the Cape Passero nursery grounds is evident, but the offshore displacement of the AlS can possibly have important consequences in the larval survival rates through offshore advection.

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CONDITION AND SURVIVAL OF ANCHOVY LARVAE IN RELATION TO HYDROGRAPHY AND FOOD AVAILABILITY IN THE OUTFLOW OF THE RIVER PO ADRIATIC SEA

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The aim of the ALICE programme (Anchovy Larvae In Contrasting Environments, a joint study of ICRAM and PML) was to investigate the survival of anchovy larvae in the northern Adriatic and specifically to test the hypothesis that wind mixing disrupts layers of food concentration in the water column and leads to poor survival of the larvae.

This was carried out by means of a field sampling programme (Bongo and FAO nets, LHPR, tlndulator, radio-buoy, CTD) to relate environmental conditions and food availability for anchovy larvae to survival of the larvae. It was supported by a complimentary laboratory based experimental programme on the development, growth and feeding of the larvae.

The main findings were as follows:

The outflow region of the river Po was shown to be an important spawning and larval nursery area for anchovy. Nutrient enrichment from the river and consequent enhanced plankton productivity is deemed to be one aspect of the favouribility of the region. The diet of anchovy larvae was predominantly copepod nauplii and copepodite stages; these organisms were shown to he more abundant in the outflow region of the river Po.

During the four week field sampling period of 1996, initially calm weather was replaced by unsettled conditions with strong northeasterly winds and high river outflow. Relatively calm weather returned gradually towards the end of the sampling period. The changing meteorological conditions were reflected in the hydrographic structure which evolved from well-stratified conditions and warm surface temperatures to a lower level of stratification and cooler surface temperatures.

General levels of abundance of food particles for anchovy larvae changed in parallel with the evolving weather conditions. Food abundance was relatively high at the beginning of the 1996 sampling cruise following the period of stable weather, then there were somewhat lower levels and an altered species composition during the extended period of poor weather and, as stable conditions returned at the end of the cruise, an increase in food abundance. However, it is likely that food levels were at no time severely limiting to larval survival.

The generally adequate feeding conditions were reflected in larval mortality which was at a similar level following the period of stable weather as after the period of wind mixing. The observed mortality rates of around 44% per day are comparable with other estimates from the Adriatic and elsewhere.

The potential survival of anchovy larvae in relation to food availability was also investigated using measures of larval nutritional condition. These methods were validated in rearing experiments on anchovy larvae carried out at a shore laboratory .

The link between the nutritional condition of anchovy larvae and food availability was evidenced both by the positive relationship between larval condition and the amount of food in their guts and by the general observation that larvae in poorer condition were found further offshore where food availability was lower.

Smaller, and probably less resilient larvae were at a generally lower level of nutritional condition than larger larvae.

However, there was no clear specific relationship between food availability on each sampling occasion and larval condition. This was attributed to the generally favourable levels of food abundance and the high degree of spatial and temporal variability encountered during the 1996 field sampling.

Thus, considering the above broad-scale results from the field surveys, some general relationships were shown between weather conditions and the feeding environment for anchovy larvae, but without any precise linkage being apparent. The results from the more detailed sampling at individual stations, in particular the pattern of vertical distribution, provided material for an examination of possible feeding relationships at a finer scale of resolution:

Bath eggs and larvae of anchovy were concentrated in the upper 15m of the water column. Food particles were generally rather more dispersed through the water column, but the highest concentrations, some 1.5x-2.5x the mean water column abundance, were invariably in the upper l0m of the water column. It is suggested that the vertical mobility of the larvae enables them to locate and exploit these layers of aggregated food particles.

Changes in stratification were reflected in similar changes in the vertical distributions of anchovy larvae and food particles; thus, when the water column was less structured, both components were more dispersed. This was shown for food particles specifically as a positive relationship between the ratio of maximum to mean food abundance (i.e. vertical concentration) and stratification in the top 15m of the water column.

The wind mixing experienced during the 1996 sampling period tended to reduce water

column stratification, and hence, at some stations, resulted in lower vertical concentrations of food particles. However, in the more inshore areas close to the river mouth, the enhanced superficial freshwater outflow which accompanied the higher winds reinforced water column stratification and maintained the vertical concentrations of food particles.

These observations lead to the conclusion that the outflow region of the river Po is also advantageous for the survival of anchovy larvae due to the contribution that freshwater flow makes to the maintenance of water column stability, and hence concentrations of food particles. That elevated mortality rates were not observed in the fairly extreme wind conditions encountered, does not discount the possibility that water column mixing can jeopardise the survival of fish larvae, but indicates more the value of stratification for their survival. There are, therefore, implications for the survival of anchovy larvae under conditions of reduced river flow occasioned, for example, by changes in climate or management regime.

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GIS APPLICATION ON THE STUDY OF THE SPATIAL DISTRIBUTION OF SMALL PELAGIC FISHES IN THE GULF OF LIONS. ENVIRONMENT OR INTERSPECIFIC COMPETITIVITY?.

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ABSTRACT

This work represents one example of the many applications developed within the framework of EU Project FIGIS (1996-1999). A group of Mediterranean research institutions worked together to test the suitability of Geographic Information Systems as research tools for the description and understanding of the marine resources distribution. One of the main features of GIS when applied to natural resources issues, is its ability to reveal or check hypothesis on time trends and spatial patterns of the resources distribution. The goal of this work was, first to graphically display on a map the distribution of several small pelagic species in the Gulf of Lions, and second, to detect some patterns (interspecific exclusion or overlapping) and to determine to which extent those patterns are affected by environmental factors viz. sea surface temperature.

Data sets used in this work come from echosounding transects carried out in the gulf of Lions during PELMED93 acoustic survey. Transects are perpendicular to the coastline and inter-transect distance is 12 NM.. Identification hauls served to identify species and estimate their proportion in the

schools encountered. Physical and meteorological data as well as geographic positioning, daytime, depth, among others werw recorded during the survey.

GIS ArcView was used at a first step to map the spatial distribution of the species in the transects, giving different symbols to represent relative abundances (in TM/NM^2). Further application of geostatistical techniques consisting of interpolation by kriging after identification of the best variogram model, lead to the display of abundance isolines in the total surveyed area, what gives a general view of the partitioning and overlapping of the space for the different species. EVA software was used to perform kriging. Generated grids were afterwards exported to IDRISI which is another GIS with better skills on the management of raster images and on the general spatial operations. IDRISI**,** finally performed the regression between different images (abundance of species and sea surface temperature).

Results showed:

- Negative relationship between SST and sardine biomass (r = - 0.8202)
- Positive relationship between SST and Anchovy biomass (r = 0.64) high dispersion, with maximum concentration around 19.5°C.
- Negative relationship between anchovy and sardine biomasses (r = - 0.32) confirmed by cross-tabulation.

Conclusions that can be derived from this work could be summarised as follows: The use of GIS has enabled the establishment and confirmation of several hypothesis regarding small pelagic distribution in the Gulf of Lions. A synergic effect of both SST and interspecifie competitiveness can not be discarded. Further studies on a longer time series basis, would be needed to discriminate between the two factors. One of the major limitations of the method is clearly the difficulty on getting a considerable number of positive hauls to produce valid kriging maps for each species. Special care has to be taken on the split in different subareas and on the treatment of the boundary lines.

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ON THE EFFECTS OF SST ON THE INTERANNUAL FLUCTUATIONS OF EUROPEAN ANCHOVY *(Engraulis encrasicolus)* CATCHES: FIRST INDICATIONS FROM THE CASE STUDY OF THE POPULATION OFF THE SOUTHERN SICILIAN COAST

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Recent results of two study projects funded by EC-DGXIV (MED96-052 and MED98-072) showed the importance of surface circulation for the reproductive strategy of anchovy population off the southern coast of Sicily. The mean path of the AIS and the permanent upwelling regime (reinforced by wind-induced events) which characterize the study area, are supposed to regulate the distribution of the spawning area and the survival rates of anchovy early stages (García Lafuente *et al.,* in press), thus possibly affecting the yearly recruitment success.

The main aim of the present working paper is to perform a preliminary time series analysis on the catch-effort data collected in the framework of the above mentioned study projects in order to verify possible relations between the observed monthly CPUE fluctuations and Sea Surface Temperature (SST) anomaly, the latter considered as a proxy of the oceanographic processes characterising the study area.

Catch-effort data used here were collected at Sciacca, the most important base port for the landings of small pelagic species along the southern Sicilian coast, from May 1997 to December 2000. Basic information refers to daily total landings of anchovies and corresponding effort of mid-water pair trawlers, as measured by fishing days. Catch per unit effort (CPUE) indexes was evaluated on a month-by-month basis dividing total anchovy catch by the total number of fishing days. Missing monthly values which occasionally occurred at the ends of the fishing seasons were estimated by linear interpolation.

The SST data was obtained from a collection of SST analyses prepared at the National Center for Environmental Prediction. In particular, monthly 1x1 global SST analyses were applied. Out of the global dataset, we selected the monthly SST time series at one site off the southern coast of Sicily near Adventure Bank (geographical coordinates: 3 7° 30' N, 12° 30' E), which is located close to the main spawning area and fishing ground for anchovy in the study area (Mazzola *e t* al., 2000a, 2000b). The Smith and Reynolds (1998) adjusted OI monthly climatology (base period 1961-1990) for the above mentioned site was used to generate monthly anomalies.

The seasonal component of anchovy CPUE series was removed by differencing (lag=12 months) raw information. Cross-correlation analysis was then applied to the two monthly time series (CPUE and SST anomaly) as implemented by SYSTAT for Windows statistical software v.8.

Plots of available data seem to indicate a possible positive relation between CPUE data

and SST anomalies registered during the spawning season of the preceding year. This applies to all fishing seasons excepting 1999. On the other hand, time series analysis revealed a significant positive correlation between anchovy CPUE and SST anomaly at lag = -9. In this case, a correlation for a negative lag indicates the values in CPUE series to be related to the values in SST series nine months earlier, that is, "good" fishing seasons are associated to "greater than average" anomalies in September-November, at the end of the spawning activity and during the period of larval growth.

Taking into account that the age structure of the anchovy population in the study area seems to be dominated by the first year class (Path et al., 2001), and if the positive SST anomalies may be interpreted as a proxy of oceanographic processes able to affect the larval survival rates through offshore advection, the observed pattern of anchovy CPUE could reflect a strong dependence of the yearly recruitment success on the survival processes of the early stages one year before. It is worth noting that a similar pattern was observed by studying the stock-recruitment relationship of red mullet (Mullus barbatus L. 1758) in the same area (Levi *et al*., 2000).

The present results, associated with the evidence that acoustic evaluations of the anchovy population in the study area produce consistent results compared to CPUE data (Path *et al*., 2001), encourage the efforts of our research team towards the adoption of the hydro-acoustic approach for the estimation of larval and juvenile anchovy biomass, to be used as a useful information for the management of the resource.

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IMPACT OF ENVIRONMENTAL FACTORS ON RECRUITMENT OF ANCHOVY *(Engraulis encrasicolus)* AND SARDINE *(Sardina pilchardus)* OFF WESTERN MEDITERRANEAN

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Production of harvested fish and invertebrate populations of the western Mediterranean during the last decades suffered cyclic fluctuations which, according to Demestre *et al. (1987),* are not only dependent on fishing activities. Regardless of the long tradition in Mediterranean fisheries research the relationship between fish populations and its environment have been only sporadically studied. Recent papers (Caddy *e z al., 1995;* Daskalov, *1999;* Levi *et al., 1999;* Lloret *et al., 2001)* are focused to the role of the environmental conditions on the fish production. The area off Tarragona (northwestern Mediterranean) is one of the relatively most productive in the region. This is due to a number of environmental conditions such as: a relatively wide shelf, an important riverine input (mainly from the Ebre), and frequent episodes of strong winds.

Our purpose here is to present the results of a study relating river runoff and wind conditions with landings of anchovies and sardines off Tarragona. These two local environmental variables have been selected because they play a known important role on planktonic production in the region (Estrada, *1996;* Salat *et al., 2001).* The two species, in turn, have been selected because both they are the most abundant pelagic species with commercial data and their spawning seasons are opposite in the annual cycle. The basic working hypothesis behind this study is that recruitment of anchovy and sardine of the western Mediterranean could be influenced by the above mentioned environmental factors, through enhancing the water fertilisation, during the respective reproduction season of these two species.

A series of monthly total catch records of anchovy *(Engraulis encrasicolus)* and sardine *(Sardines pilchardus)* landed in Tarragona harbour was available for the period January *1990 - April 1998.* Fishing effort (number of boats and monthly time at sea) remained nearly stable during the study period. Daily wind data (speed and direction, *1990-98)* were obtained from the meteorological station of Cambrils (near Tarragona). We computed a "wind mixing index" which is the monthly mean value of the third power (cube) of the wind speed (Bakun and Parrish, *1991).* Monthly mean flow data (m^3/s) of the Ebre River *(I990-98)* recorded near to its mouth were obtained from the Confederacion Hidrografica del Ebro.

To evaluate the possible relationship between yield and the selected environmental variables, we constructed a transfer function model (Box and Jenkins, *1976)* using the monthly data. We used only the data for those months when each one of the species was reproducing, i.e. the time period when eggs and larvae are in the water, which is a key determinant of interannual survival variablility. Reproduction periods considered were April-August for anchovy and November-March for sardine. Transfer function models were built following the Box and Jenkins' modelling strategy (Box and Jenkins, *1976)* using the software package TESS developed by the Polytechnical University of Catalonia (Prat *et al., 2001).* Thus, we compared the environmental

conditions only during the spawing seasons with the landings obtained afterwards.

The four transfer function models between yield (dependent) and environmental variables (independent) carried out showed that only the catch of anchovy had a significant positive correlation at a time lag of 12 months with river discharges during the reproduction seasons. The r^2-value found in this case was 0.63. This indicated that 63% of the variance of the time series of catch was explainable by the variance of the Ebre flow with a time-lag of 12 months. However, there was not found any relationship between landings of anchovy and the wind mixing index. In addition to this, sardine landings were neither related to river flow nor to the wind mixing index. Thus, the transfer function model fitted to anchovy landed in Tarragona harbour (Y_t; output) and Ebre runoff (X_t; input) is represented by the following equation: $Y_t=f(X_t)=0.204X_t$ -12 + at. In other words, every additional m^3/s of Ebre runoff during the reproduction time of anchovy adds 204 kg to the total monthly catch of anchovy obtained one year later.

Anchovy spawns and is mainly caught during summer when most of the individuals in the population are one year old (Palomera, 1992; Pertierra and Lleonart, 1996). Therefore, catches of anchovy can be considered as a proxy of the recruitment. The results showed that an increase of the Ebre runoff during the reproduction period of anchovy is favourable for the spawners and early stages (probably through the increased productivity at surface in the area influenced by the discharges), that finally enhances recruitment (reflected on catches) of anchovy one year later.

Although the model establishes a significative positive correlation between anchovy recruitment and river runoff, it does not explain all the variations in recruitment. This indicates that other variables, such as the parental stock biomass or density dependence processes may also influence the year class strength. Freshwater discharges have been demonstrated to enhance recruitment of anchovy in other areas of the Mediterranean, e.g. in the Gulf of Lions (Lloret *et al.,* 2001), the northern Adriatic (Levi *et al.,* 1999) and the Black sea (Daskalov, 1999). The extension of the surface area influenced by the river discharges can also favour the survival of anchovy larvae as pointed out in Satiates *et al. (2001).*

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A COMPARATIVE STUDY OF THE SPATIAL DISTRIBUTION THE EARLY STAGES OF ANCHOVY AND PATTERNS OF MEDITERRANEAN SEA

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In the last decade considerable research has addressed the horizontal and vertical distribution patterns of the early stages of anchovy (Palomera *1991,* Garcia & Palomera *1996),* but much less attention has focused on the eggs and larvae of pilchard in the region. In the NW Mediterranean the larvae of both anchovy and pilchard are usually found over the continental shelf. The present study was performed on the continental shelf opposite the Ebro River, an area characterized by the outflow of inland waters from the river (Salat *et al.,* in press) and important mesoscale activity (Wang *et al. 1988).* These features contribute to global productivity in the region, but they may also have a adverse effects by dispersing the larvae. Thus, a knowledge of the horizontal distribution patterns of the eggs and larvae requires an understanding of coupling between vertical distribution patterns and the ocean dynamics. In the present study we examined whether the different environmental conditions during the spawning seasons for anchovy (summer) and pilchard (winter) influenced the horizontal and vertical distribution patterns of the eggs and larvae of these species on the continental shelf off the Ebre River (NW Mediterranean).

The present study was based primarily on two Lagrangian experiments, each during the spawning season of one of the two target species (summer for anchovy, winter for pilchard). The sampling area was the same in both cases, opposite the Ebro River Delta (NW Mediterranean). The first step was to perform a survey of the horizontal distribution of eggs and larvae. In both studies samples were initially examined on board to locate patches of eggs and/or larvae for release of the drogues, the start of the Lagrangian experiments. Stratified plankton samples were collected using a Longhurst-Hardy Plankton Recorder (LHPR) net system. In the anchovy survey Lagrangian experiment 7 stations were sampled in the daytime and 3 at night. In the pilchard experiment 7 stations were sampled in the daytime and 6 at night.

Peak spawning for anchovy in the NW Mediterranean occurs between May and July (Palomera 1992). Direct information on pilchard spawning in this area is scarce. A study of adults (Larraneta 1960) and a two year survey based on monthly plankton sampling at two isolated inshore stations (Palomera & Rubies 1979, Palomera & Olivar 1996) indicate that peak pilchard spawning takes place from December to March. The horizontal distribution patterns of eggs and larvae recorded on the two surveys carried out during the present study have corroborated that they were performed during the respective main spawning season for each species.

The pelagic eggs and larvae of both species are present in the upper 70 m of the water column, but there were differences in the preferential vertical distribution and migration patterns. Maximum concentrations of anchovy eggs and larvae were located in the upper 20 m, while for pilchard concentrations extended down to deeper levels between 10 and 40 m. Vertical displacements by the larger larvae at night were recorded for both species, but with opposite patterns. While anchovy larvae tended to aggregate in the upper 10 m, pilchard larvae exhibited greater dispersal at night, with a preference for levels below 30 m.

In the NW Mediterranean in summer, as a general rule, nutrients are depleted at the surface because of horizontal stratification produced by the thermocline, which limits vertical mixing to a very shallow layer. In such conditions productivity in the water column is confined to the Deep Chlorophyll Maximum (DCM) (Estrada & Salat 199). During winter low temperatures and vertical mixing associated with wind storms affects the entire surface layer (usually down to more than 100 m). Mixing over the continental shelf involves the water column as a whole, carrying nutrients to the entire euphotic zone. Consequently, in winter maximum productivity over the continental shelf is centred near the surface.

It can be concluded that light and food availability regulate the vertical distributions of the larvae of these two species. In spite of the apparently different vertical distributions of the species, their larvae tend to aggregate in the more productive layers during the hours of daylight. In periods of thermal stratification, anchovy larvae that migrate upward to fill their gas bladders at night are confined to those layers by the thermoeline during the nocturnal resting period. In winter there are no physical barriers to keep pilchard larvae confined to the upper layers, so that slow sinking may occur during the period of darkness.

The horizontal patterns for the egg and larval distributions of *Engraulis encrasicolus* and *Sardine pilchardus* observed in this study can also be related to the areas of higher productivity. In summer, the chlorophyll values at the DCM are higher in the vicinity of the frontal zone on account of the associ-

ated mesoscale activity (Estrada and Margalef, 1988; Maso *et al.* 1998). In the survey carried out in June 1996, anchovy larvae were mainly concentrated near the shelf break, the main frontal area. Thus, the horizontal distribution of these larvae mirrored the productivity distribution. In winter productivity is higher over the continental shelf than further offshore, because vertical mixing there spans the entire water column. The horizontal distribution of pilchard larvae found in February 1997 also reflected this pattern, with peak abundance recorded in the centre of the continental shelf.

The fact that large concentrations of anchovy larvae were found near the main frontal area means that they are exposed to horizontal displacements caused by the shelf-slope current associated with the front. In terms of potential dispersal, that pattern contrasts with the distribution for pilchard centrally on the shelf, where currents are less intense and circulation is usually anticyclonic (Font *et al.,* 1990). Consequently, the early stages of pilchard are less exposed to horizontal displacement and will tend to remain inside the 200-m isobath.

Therefore, by way of a general conclusion, both the horizontal and the vertical egg and larval distributions recorded indicate that the spawning strategies of the two species are closely related to the main productive mechanisms operating in the region. The different distribution patterns found can be attributed to the different seasonal mechanisms that act to enhance productivity.

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LARVAL FISH ASSOCIATIONS IN PELAGIC FISHES TRACE INTER-ANNUAL ENVIRONMENTAL VARIABILITY IN THE NE AEGEAN SEA

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The timing and intensity of spawning in fishes is believed to be adaptive, reflecting the phase of the mean seasonal cycle of the environment favorable for offspring survival. The present study was directed towards an understanding of the factors that influence the timing and intensity of spawning of the eastern Mediterranean pelagic fishes during early summer (May-June), which is a transitional period for both the physical environment and spawning of fishes. It is also the period of maximum abundance and species diversity for fish larvae in the plankton.

The analysis of satellite images taken on a weekly basis from 1981 to 2000 revealed that sea surface temperature (SST) in the NE Aegean Sea (eastern Mediterranean) exhibited an intense peak in 1994 and 1995. We examined inter-annual variability in larval abundance of pelagic fishes during June 1993, 1994, 1995 and 1996, in an effort to identify multispecies ichthyoplankton responses to the observed SST variability.

Ichthyoplankton, hydrological and zooplankton displacement volume data were available from four surveys carried out in 7-11 June 1993, 19-23 June 1994, 15-22 June 1995 and 6-14 June 1996 in the NE Aegean Sea. There were significant ($P<0.05$) among-year differences in the mean larval abundance of pelagic species, which were associated with differences in the environmental conditions. The NE Aegean Sea was cooler, fresher and richer in zooplankton during June 1993 and June 1996. Mean larval abundance of small-sized pelagic species (anchovy and most mesopelagic species) was higher in 1993 and 1996, whereas that of the middle-sized pelagic species (i.e., *Sardinetla aurita,Trachurus mediterraneus, Scomber japou*icus and Auxis *rochei)* was higher more abundant and/or frequent in June 1994 and June 1995. Such differences, which indicate differences in reproductive strategies among pelagic fishes, are discussed in terms of `income' versus `capital' breeding as well as in terms of inter-specific differences in the larval performance abilities. The observed multispecies ichthyoplankton associations of smallsized and middle-sized pelagic fishes might be adaptive and result from similar responses among species to the pelagic environment, especially to prey fields of zooplanktivorous adults.

Inter-annual variability in ichthyoplankton during the transitional period of spring - early summer may trace variability in meteorological and physical processes and be particularly useful in highlighting shared or contrasting reproductive adaptations and their response to inter-annual climatic variability.

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ANCHOVY AND SARDINE IN GREEK WATERS: A REVIEW OF BIOLOGICAL, ECOLOGICAL AND FISHERIES ASPECTS RELATED TO ENVIRONMENTAL VARIABILITY

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In this report we present the available data sources and studies concerning the biology, ecology and fisheries of anchovy and sardine in Greek waters, especially those related to environmental variability, as well as various analysis methods that have been used for studying small pelagic fisheries-environmental interactions. Statistical data on commercial landings are available since 1964 (National Statistical Service of Hellas, NSSH) for 16 statistical fishing subareas. Details on the sampling schemes (i.e., stratified random sampling), the resolution of collected data of landings (i.e., annual and monthly landings) and effort (i.e., number of boats, engine horsepower and tonnage, aggregated by major gear) and their accuracy are provided in Stergiou *et al.* (1997a). In addition, since 1996, the Institute of Marine Biology of Crete (IMBC) collects data on catch per fishing day, aggregated by major gear and fishing subarea, over a net of 21 stations. Both sources of data indicate that landings and catch/day of anchovy have declined in recent years whereas those of sardine have rather remained constant.

Stergiou and Christou (1995) and Stergiou *et al.* (1997b) have evaluated 16 modeling techniques on the basis of their efficiency to model and provide accurate operational forecasts of 16 annual and 16 monthly commercial NSSH landing series, including those referring to anchovy and sardine, in Greek waters. The development of fits and forecasts was based on the following four general categories of forecasting techniques. (a) Deterministic simple or multiple regression models incorporating different exogenous variables, including climatic ones; (b) univariate time series models (Brown's, Holt's and Winter's exponential smoothing; ARIMA); (c) multivariate time series techniques (harmonic and dynamic regression, vector autoregression); and (d) the "biological" exponential surplus-yield model. Fits (for 1964-1987) and forecasts (for 1988-1989) obtained by the different models were compared with each other and with those of a naive method and an empirical one (i.e., combination of forecasts) using 32 different measures of accuracy. The results revealed that although harmonic and multivariate regression models outperformed, in terms of fitting accuracy, the remaining models, in terms of forecasting performance, not a single best approach was found. In contrast, the univariate ARIMA, closely followed by the multivariate dynamic regression models, outperformed the remaining ones in terms of both monthly fitting and forecasting accuracy. Some of the empirical models built also had interesting biological/oceanographic explanations. Thus, the univariate ARIMA, the multivariate dynamic regression and the vector autoregression model all predicted/indicated (a) persistence of landings; (b) landing periodicity of 2-3 years; (c) that climate might affect long-term trends and short-term variation in the landings of anchovy and sardine; and (d) variability and

replacement of anchovy by sardine landings are not due to chance and wind activity over the N Aegean Sea might act as a forcing function. Recently, the modeling efficiency of the X-11 census technique has also been evaluated in the case of anchovy (Stergiou 2000).

It is noteworthy that there is an absence of regular, long time series of data on biomass and recruitment of anchovy and sardine throughout the Greek waters, inasmuch as experimental sampling and surveys are generally highly discontinuous at both temporal and spatial scales, being mainly linked to the existence of on-going projects and end with the end of the specific project (e.g. Tsimenides 1989, Machias *et al.* 1997, 1999, 2000; Somarakis *et* al. 1997; Drakopoulos *et* al. 2000). This represents an impediment to the study of the effect of environmental variability on small pelagic species. Some examples are provided below.

The results of acoustic research surveys show that the abundance of anchovy, which ranges between 40000 and 45000 t in the N. Aegean Sea and between 14000 and 15000 t in the Central Aegean and Ionian Seas, and sardine has declined in recent years. In addition, since 1996 a project was initiated by the Laboratory of Ichthyology (Aristotle University) concerning collection of biweekly data on length, weight, sex ratio and condition of both species in the NW Aegean Sea. The results clearly indicate that the mean length of sardine and anchovy in the NW Aegean Sea has declined in recent years, along with the decrease in biomass. The potential effect of environmental variability on such a decline is a matter of further studies.

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INTERACTION BETWEEN SPATIAL AND TEMPORAL VARIABILITY IN THE WESTERN MEDITERRANENAN AT BASIN, SUB-BASIN AND SCALE: OBSERVATIONS AND MODELING

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IMEDEA, Institut MEditerrani D'Estudis Avançats (Mediterranean Institut for Advanced Studies) is a joint research centre between the University of the Balearic Islands and the Spanish Council for Scientific Research (CSIC) located in Esporles, Mallorca. At IMEDEA, the GOI-Grupo de Oceanografia Interdisciplinar investigates the open ocean and the coastal environment using an interdisciplinary and integrated approach. More specifically the GOI_FIS is involved in different studies, from open ocean mesoscale dynamics to coastal processes, and from climatic time scales to short-period shelf waves. In terms of methodology, GOI_FIS combines observations (remote and in situ from oceanographic cruises) and numerical modelling. Here we review the most important results obtained on the variability of the Mediterranean by our group in recent years.
Background: the Mediterranean Sea is characterized by a well defined temporal and spatial variability associated with the thermo-haline circulation that is mostly concentrated on the slope areas. Addressing the temporal variability, the western basin is characterised by a clear seasonal and inter-annual

variabilities that have been fairly intensively studied in the last ten years using *in situ* data in different sub-basins, numerical models and time series at selected places. Also important is the spatial variability associated with frontal structures and that is mostly dominated by strong mesoscale eddies and filaments (internal Rossby radius of the order of 12 km) and also by significant interactions between theses frontal structures and bottom topography such as canyons,

Mesoscale variability and **vertical velocity computation:** in the last 20 years studies have addressed the computation of vertical velocity from oceanographic cruise data. In our case, we have obtained estimates of vertical displacements in frontal regions, mainly in the Alboran Sea (Tintore *et al., J. Phys. Oceanogr.,* 1991) and later in the Balearic fronts (Pinot *et al., Prog. In Oceanogr., 1995).* Theses studies showed vertical velocities of the order of tens of meters per day, an order of magnitude higher than the highest vertical velocities characteristic of upwelling regions.

Interannual variability in the Western Mediterranean at sub-basin scale (observations): the Balearic channels are key places to monitor the circulation in the Western Mediterranean (WM). These channels allow adequate monitoring of the meridional fluxes between the (thermo)dynamically well contrasted northern and southern WM regions and are therefore ideal places to assess their time variability. Observations in the channels: between 1996 and 1998, five instrumented moorings were deployed and 14 repeated hydrographic surveys were carried out in the area. From the analysis of these data, it appears that the circulation is characterized by two flow regimes. While in 1996 the transport through the Ibiza channel was restricted by the presence of an eddy of Winter Intermediate Water (WIW) trapped to the north of the passage, in 1997, WIW were not detected and a free north-south circulation was allowed.

Interaction between sub-basin interannual variability and basin scale circulation (modelling): numerical experiments carried out with a 3d primitive equation model of the overall Mediterranean Basin, confirm the existence of a close link between the interannual variability of the north-south transport through the Balerie Channels and the atmospheric conditions characteristic of severe winters when WIW forms in the north. When an artificial increase of the model climatological winter atmospheric fluxes in the Gulf of Lyons is performed, it is observed a major change on the model water transport through the Ibiza channel, thus tested that the Western Mediterranean variability could be due, to some extent, to an intrinsic variability of the Mediterranean system. The fact that the climatological forcing doesn't produce the WIW (waters below 13 degrees are not present in the surface climatology), but the model results with this forcing show an important interannual variability, can be a part of the explanation of the variability observed in the channels. In summary, it appears that the interannual variability of the north-south exchanges through the Balearic channels is strongly modified and controlled by the presence of WIW to the north of the Ibiza channel but also by a more general variability that can be related to an intrinsic variability of the Mediterranean system.

Local scale interaction between fronts and canyons (observations and modelling):
we initially studied the importance of the temporal variability at scales of acterizes the northern current and deep

topographic canyons. We found that canyons were regions of preferential exchange of water masses between the open ocean and the coastal area and that open ocean larvae where found trapped over the shelf in an anticyclonic eddy *(Alvarez et al., J. Geophys. Res., 1996).* We later used a limited-area fine-resolution primitive equation model to simulate the three dimensional circulation and the adjustment processes in the canyon area under different wind forcing conditions. Our results appear to be in fairly good agreement with in situ physical and bio-geochemical data collected in Blanes Canyon or comparable canyons of the world ocean. The three-dimensional motion obtained in the model can explain some of the observed patterns of larvae and exchanges between the coastal zone and the open sea *(Ardhuin et al., J. Geophys. Res., 1999).*

Western Mediterranean teleconections: the influence of NAO and ENSO on the SST of the Western Mediterranean: in the past years there has been an increasing interest in the study of the interactions between the Mediterranean Sea and widely separated part of the atmosphere. Correlations between ENSO or NAO and different meteorological or oceanic indexes in the Mediterranean have show the existence of a clear relation between global and local phenomena. have been studied. The influence of those global scale phenomena are crucial for understanding local variations in the Mediterranean area. Knowledge in the coupling of the atmosphere-ocean system is a key factor for understanding all the processes many of the processes occurring in the upper sea layers (i.e. heat transfer, salinity, waves, etc.).

EASY: A GIS TOOL FOR THE INTEGRATION AND ANALYSIS OF MULTIVARIATE FISHERIES OCEANOGRAPHY DATA

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Central to the problem of resolving causal linkages between environmental variables, recruitment processes and the dynamics of marine populations more generally is the characterization of patterning variability over a range of spatio-temporal scales. By facilitating the integration and visualization of diverse spatially referenced datasets, geographic information systems (GIS) likely will play a significant role in supporting such fisheries oceanography research. To be of greatest utility GIS tools must not only provide a software environment in which to effortlessly and interactively render graphical overlays of diverse data types using a variety of plot types in a dynamical, time-referenced manner. They should also provide a framework for the integration of both statistical and mechanistic models for data analysis, and capitalize on advanced technologies and the Internet as a medium for both data acquisition and the dissemination of value-added data products. Here we describe a custom oceanographic GIS package called EASY that supports these critical features, and briefly review the use of this software in the "Census of Marine Life" initiative.

Environmental Analysis System (EASY) is a sophisticated but intuitive, PC-based geographical information system designed for the storage, dissemination, integration, analysis and dynamic display of spatially referenced series of diverse oceanographic data.

EASY has been custom designed with the particularities of oceanographic applications, the needs of marine research and educational communities, and pathways for information acquisition and exchange in mind. It facilitates interfacing of multivariate oceanographic data, including satellite and other imagery in a range of standard formats, with statistical algorithms and mechanistic models (eg. biooptical algorithms, diffusion models).

EASY graphically renders dynamically in time, within their proper geo-spatial context, both field and remotely sensed data and model outputs as diverse types of plots, including vector, bubble, contour, false colour imagery, and both time domain, correlative, and statistical diagnostic XY-plots. Data at particular, userspecified locales can be drilled and interrogated in a variety of ways. Vertical structure in data, important in oceanographic applications, is depicted as vertical contours for user defined transects or depth profiles at interactively selected point locations. Time series of measurements and dependencies between data at individual stations can also be visualised interactively as XY-plots.

Perhaps the single greatest constraint to rapid GIS application development is the ingestion of oceanographic data from diverse, decentralised sources and maintained in a variety of formats. EASY provides a range of tools that help address these challenges. In addition to a wizard for ingestion of data in flat-file ASCII format, EASY allows direct access to and dynamic querying of both local databases (eg. MS ACCESS, Paradox) and institutional scale, remote database servers (such as ORACLE, Informix etc) via SQL queries using standard database connection interfaces such as ODBC and ADO. EASY also supports data ingestion via the DODS protocol (Distributed Ocean Database System), the emerging standard for the exchange of oceanographic datasets developed at the University of Rhode Island, and currently used by several oceanographic institutions including Woods Hole. Furthermore, EASY also supports both FTP and HTTP Internet protocols for the automatic acquisition and ingestion of imagery data stored on remote network servers. These capabilities ensure that EASY will be able to directly tap all technical database management frameworks that are likely to be employed by oceanographers and their host institutes.

In addition to data acquisition, EASY also facilitates broad access to data, integrated visualization products and analytical tools over the Internet via the software's Netviewer plug-in. Netviewer extends EASy's capabilities to that of a GIS web-server, permitting the deployment of GIS applications across the Internet (http://netviewer.usc.edu/ezclient/netview.htm). Unlike catalogues of data products currently available on the Web, Netviewer permits users to harness almost the full functionality of the desktop version of EASY dynamically via the Internet. Using only their web-browser software, users can interactively define data variables to overlay, view data either in custom order or in temporal sequence as a simulation run, zoom to areas of interest and highlight subsets of project data for downloading in standard formats.

EASY has been used in a range of national and international oceanographic projects, including the storage and mapping of biooptical parameters in the Atlantic ocean and Mediterranean Sea, and most recently the GMBIS (Gulf of Maine Biogeographical Information System - GMBIS) project funded under the Sloan/NOPP `Census of Marine Life/OBIS' programme. The basic objective of GMBIS is to develop a methodological framework for enhancing access to and assimilation of existing data relevant in

marine biogeographical and ecological studies. End-to-end viability of the approach is demonstrated in the context of a pilot application for the Gulf of Maine using an extensive archive of multidisciplinary oceanographic data for the region maintained by the Bedford Institute of Oceanography and the Atlantic Reference Centre. As an illustration of EASy's functionality and utility as a tool for fisheries oceanographic research, the GIS application developed for the GMBIS project will be demonstrated.

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MULTIVARIATE ANALYSIS OF THE PELAGIC FISH COMMUNITY OF KLANG STRAIT (MALAYSIA) IN RELATION TO ENVIRONMENTAL FACTORS

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ABSTRACT

Pelagic fish distribution and abundance of Klang Strait were studied based on trawl survey with measurement of water and sediment characteristics were carried out from November 1996 to April 1998. A total of 29 species belonging to 10 families were recorded based on 7059 specimens examined.
The most common families recorded were Engroulididae, Clupeidae, Stromatidae, Carangidae and Polynemidae during the study period. Most of the species comprised of young juveniles. Multivariate analysis was used, and the relationship between the distribution, abundance of pelagic fish and thirteen abiotic factors were discussed. Canonical Correspondence Analysis (CCA) indicates that the most important abiotic factors controlling the distribution and abundance of pelagic fish were water depth, salinity, turbidity and sediment pH.

Keywords: Multivariate, Pelagic fish, Environmental factors, Klang Strait.

MONITORING AND ECOSYSTEM ANALYSIS

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In the Mediterranean, as elsewhere, changes in marine ecosystems result from variations in climate, in fishing pressure, in pollution, and in river discharge.

Although the principal concern of this workshop is the relationship between environmental variability and that of small pelagic fisheries, full understanding of fishery variability will require information on all of these forcing functions.

To establish the relationship between environmental and fish variability, it is essentialthat these variables be adequately monitored nd that the resulting data be shared. A firststep is to identify existing monitoring programs and the disposition of the data theyproduce. As monitoring develops, it is essential that the data are quality controlled, reely exchanged, and that their location and vailability are made known to participants. final necessary function is the objectiveinterdisciplinary assembly and analysis ofdata from an ecosystem point of view. Even with adequate arrangements for datacollection, exchange, and analysis, themechanisms linking changes in populations of small pelagics with changes in ecosystem forcing require in most cases to be elucidated. A cooperative research agenda could result from discussions at this and subsequent workshops.

Achievement of all these actions requires the commitment and financial support of interested governments and appropriate institutional arrangements to deal with both the operational questions of monitoring, data exchange and analysis and the promotion, development and execution of the research agenda.